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HEREDITY OF EMBRYONIC CHARACTERS

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GENETICS has reached certain conclusions as to the nature of the germ-material that have an important bearing on the interpretation of the localization of the hereditary elements that influence development. Most of the genetic information has come from a study of the inheritance of the characters of adult animals and plants, but it is not without significance to find that the same conclusions can be derived from a study of the characters shown by embryos and larval forms. It would be out of place here to give the evidence for Mendel's theory of heredity, but its conclusions can be drawn upon and its principles illustrated by the inheritance of larval and embryonic characters. The most complete evidence comes from the caterpillars of the silkworm moth (Bombyx mori), especially from the work of two Japanese investigators, Toyama and Tanaka. Many races of silkworms are cultivated. The caterpillars show racial differences, especially in their color markings and in the color and shape of the cocoons. The heredity of more than a dozen different types of caterpillars and of several kinds of cocoons has been worked out. In addition, the color of the eggs and young embryos enclosed in the egg have furnished important evidence of "maternal inheritance," as has also the number of broods produced each year.

HEREDITY IN SILKWORMS

Toyama ('06) showed that when a race with striped caterpillars is crossed to a common pale race, all the resulting caterpillars are striped. If these are reared and the moths inbred there are produced 3 striped (1376) to 1 pale (417). The two races differ by one factor difference, and the results are like those found by Mendel in peas and explicable on the assumption that in the germ plasm

of the hybrid, the element for striped (that comes from one parent) separates from the element for pale (that comes in from the other parent). Half the eggs of such a hybrid contain the striped element and half that for pale.

Similarly in the hybrid male, half the sperm carry the element for striped and half for pale. Chance meeting of any egg by any sperm will give one pure striped to two hybrid striped to one pale, *i.e.*, 3 striped to one pale. Toyama also showed that when a race producing yellow cocoons is bred to a race with white cocoons, the offspring (F_1) produce yellow cocoons. If the F_1 moths are inbred, they produce three yellow cocoons to one white.

Toyama made crosses in which both larval and cocoon characters were involved. A pale race spinning yellow cocoons was bred to a striped race spinning white cocoons. The offspring were striped and produced yellow cocoons. When these were inbred they produced 9 striped, spinning yellow cocoons; to 3 striped, spinning white cocoons; to 3 pale, spinning yellow cocoons; to 1 pale, spinning white cocoons. This is the characteristic Mendelian ratio when two pairs of characters are present in a cross. If the members of each pair separate (segregate) in the hybrid, and if the separation of one pair is independent of that of the other pair, there should be produced in equal numbers four kinds of eggs and likewise the same four kinds of sperm, namely, striped yellow, striped white, pale yellow and pale white. If any one of these four kinds of eggs may be fertilized by any one of the four kinds of sperm there will be 16 possible combinations. If one remembers that striped dominates pale (when both are present) and yellow dominates white, these 16 combinations fall into four classes in the ratio of $9 : 3^a : 3^b : 1$ shown in the square below, where the dominant characters are underscored.

Eggs	Striped yellow	Striped white	Pale yellow	Pale white
Sperm Striped yellow	*Striped yellow* *Striped yellow* (9)	*Striped* white *Striped yellow* (9)	Pale *yellow* *Striped yellow* (9)	Pale white *Striped yellow* (9)
Striped white	*Striped yellow* *Striped* white (9)	*Striped* white *Striped* white (3^a)	Pale *yellow* *Striped* white (9)	Pale white *Striped* white (3^a)
Pale yellow	*Striped yellow* Pale *yellow* (9)	*Striped* white Pale *yellow* (9)	Pale *yellow* Pale *yellow* (3^b)	Pale white Pale *yellow* (3^b)
Pale white	*Striped yellow* Pale white (9)	*Striped* white Pale white (3^a)	Pale *yellow* Pale white (3^b)	Pale white Pale white (1)

Later ('12) Toyama discovered that there is a race that is re-

cessive for white cocoon color and another race that is dominant for white cocoon color. If the recessive is crossed to a race with yellow cocoons the offspring produce yellow cocoons. If these F_1's are inbred they give 3 yellow cocoons to 1 white. On the other hand if a dominant race is bred to a yellow-cocoon race the offspring produce white cocoons. If these F_1's are inbred the expectation is 3 white cocoons to 1 yellow.

Caterpillars that spin yellow cocoons have yellow colored blood; those that spin white cocoons have colorless blood. The color of the blood can be seen through the skin, particularly on the inside of the abdominal legs. The caterpillars in the last cases could be separated according to blood color as well as by the cocoon color. The outcome would be the same.

In addition to the kinds of caterpillars of the silkworm moth described above, there are several other characteristic types whose inheritance has been studied by Tanaka ('13, '14, '16). The factors of four of these (S, Z, M, N) were found to be dominant to four other types taken as allelomorphs (s, z, m, n), the latter when present alone producing a "plain coat." Later, Tanaka found that three of these (S, N, M) represent multiple allelomorphs; that is, each is a modification of the same factor; hence, only two of them can occur in the same animal at the same time (thus SN or SM or NM). Another factor Q (quail) is also said to be an allelomorph of S and M, hence of N also. The coloring of the larva homozygous (pure) for two of these factors (SS or QQ) is somewhat different from that of the combination of two of them (SQ for example). Tanaka also made the interesting discovery that the factor for yellow cocoon color (Y) is linked with each of these four allelomorphs. This means that when from one parent one of the factors (S, M or Q) enters a cross combined with yellow cocoon and from the other parent there enters another one of the caterpillar colors combined with white cocoon (two pairs of factors) there is not found in the second generation a 9:3:3:1 result, but a modification of the ratio due to the combination that went in together (SY on one side and My on the other) tending to remain together in the second generation, producing there a higher percentage of each combination that went in than expected in free assortment of the two pairs (S and M and Y and y). This phenomenon, known as linkage, is also often met with in crosses when adult characters are studied. It finds a rational explanation in the view that linked characters are carried in the same chromosome. Thus, in the above crosses, the factors for striped (S) and yellow cocoon (Y) character are carried in one chromosome and the character moricaud color (M) and white (y) in the corresponding chro-

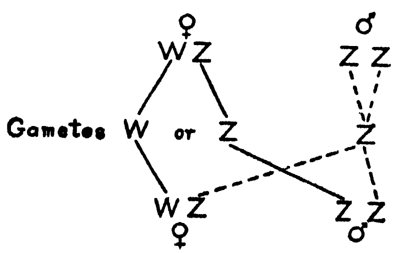
mosome of the other parent. These two chromosomes meet in the hybrid and separate when the germ-cells of the hybrid mature, giving two kinds of eggs (SY and My) and two kinds of sperm. If nothing further than this happened in the hybrid, then chance union of any egg with any sperm would give only the following combinations, 1 SYSY (striped yellow) : 2 SYMy (striped yellow) : 1 MyMy (moricaud white). The combinations that went in together would come out together, or, in other words, there would appear in F_2 only the two parental types in the ratio of 3 : 1. But the situation is not quite so simple as this, because recombinations of the characters that went in also appeared in the second generation, although, as stated above, not in the numbers expected (9 : 3 : 3 : 1) on free assortment of the two pairs. The explanation of this situation is also clear to-day for it has been shown that even when hereditary factors enter the cross in the same chromosome there is an exchange of factors in the hybrid between this chromosome and its mate. This is the familiar phenomena of crossing over. Since the interchange is not as free as when the pairs in question lie in different pairs of chromosomes the numerical results are correspondingly altered. Tanaka has shown in the female silkworm that no crossing over takes place (complete linkage) while, in the male, crossing over does occur to some extent (partial linkage).

Heredity in Other Moths and Butterflies

The inheritance of a few characters in other species of moths has also been studied. Goldschmidt ('21) records that the black type of caterpillar of the nun (Lymantria monacha) is dominant over the light type; the two characters behave as a single pair of Mendelian units. In an earlier account ('17) of crosses between different races of the gypsy moth (Lymantria dispar) a more complex situation is described by Goldschmidt. The different races of the moth spread over Europe and Asia have different races whose caterpillars show constant differences of pigmentation. The F_1 offspring are "about intermediate," the F_2 generation breaks up roughly into 3 light (medium) to 1 dark, if young stages of the caterpillars are alone considered. This was interpreted to mean that the degree of coloring in the different races is due to a series of multiple allelomorphic factors with different powers to produce pigment. As yet no sufficient data has been given to establish such a view. Goldschmidt concluded further that the factors in question are only different quantitative amounts of the same factor. Speculating further along these lines Goldschmidt assumed that by selection of the fluctuations of the factors (genes) in a plus or a minus direction a new mean could be established. The evidence

that he appealed to is quite insufficient to establish such a conclusion that has been shown not to be true in other cases where a more critical test has been applied. In addition to the difference between young larvae Goldschmidt also found that characteristic changes in the pigmentation of the caterpillars of different races take place as they pass from molt to molt. Light caterpillars remain light through the entire larval life in some races. In other races the caterpillars may become darker in some cases than in others. Medium light caterpillars of differing degrees may also change to dark. These differences were also ascribed to differences in "quantity" of the allelomorphic genes.[1]

In the adults of several animals (man, fish, flies and moths) there is a peculiar type of Mendelian heredity in which the character in successive generation follows the known distribution of those chromosomes connected with sex determination. There is also a case of this kind in the caterpillar of the silkworm moth where Tanaka ('22) found that the gene of one of the several types of "translucent" worms behaves in inheritance as though it were carried by one of the Z chromosomes. In this moth, as in others of this order, the female is supposedly heterozygous for the Z chromosome (WZ) and the male homozygous (ZZ). Thus—

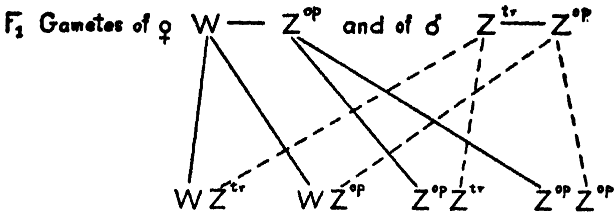


The translucent character is recessive to the normal or opaque skin—the difference depending on the presence of white granules in the more opaque skin.

In a female moth of a race with translucent larvae (WZ^{tr}) is mated to a male of a race with opaque larvae (Z^{op} Z^{op}), the daughter caterpillars (WZ^{op}) are opaque like the father, because they get this single Z^{op} from him; the sons (Z^{tr} Z^{op}) also are opaque, because the opaque character (Z^{op}) dominates the translucent character (Z^{tr}). If the moths from these F_1 caterpillars are inbred, half the

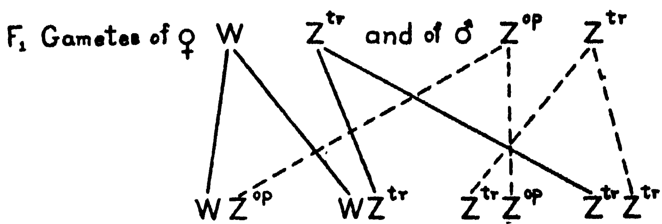
[1] In some wild races of the gypsy moth (*Lymantria dispar*) the caterpillars have a white streak along the dorsal midline; in other races the caterpillars have a broad black band along the back. When moths of these races are crossed the first generation caterpillars are black. When the F_1 moths are bred, the F_2 caterpillars are black or striped in the ratio of three black to one striped. This result was obtained by Klatt ('19) and confirmed by Baltzer ('20).

F_2 daughter caterpillars are translucent, half are opaque and all the F_2 sons are opaque. Thus:



The ratio is 1:1:2. It is apparent that the translucent character of the grandmother's race is transmitted to half the granddaughters and to none of the grandsons, although half of the grandsons carry one factor for translucent. This redistribution of the character conforms to expectation if the pair of genes involved is borne by the Z chromosomes of the two races.

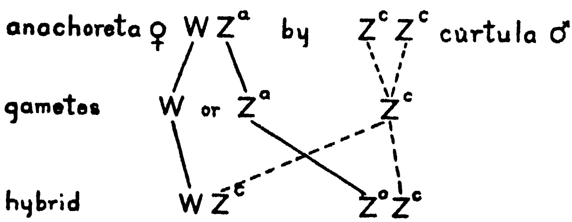
The converse experiment is equally instructive. If a female moth of a race with opaque larvae (WZ^{op}) is mated to a male of a race with translucent larvae (Z^{tr} Z^{tr}) the daughter caterpillars (WZ^{tr}) are translucent like their father, because they get their single Z^{tr} from him, and the sons (Z^{op} Z^{tr}) are opaque because of the dominance of the opaque character. If the moths from these F_1 caterpillars are now inbred half the daughter caterpillars are opaque, half are translucent, and half the male caterpillars are opaque, half are translucent. Thus:



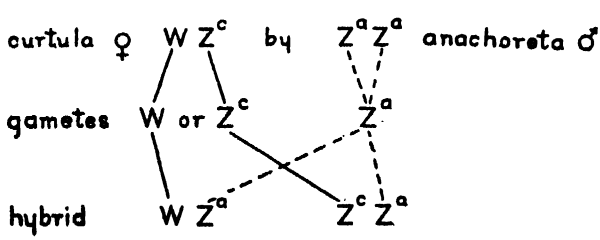
The ratio is I:I:I:I. Here the translucent character of the grandfather is transmitted to half of the granddaughters and to half of the grandsons. This redistribution of the character conforms again to expectation based on the behavior of the chromosomes.

Federley ('10) has described a case of sex-linked inheritance in a species-cross between the moths Pygaera anachoreta and P. curtula. The male and female caterpillars are alike in each species, but the caterpillars of one species are different from those of the other. When P. anachoreta is the mother and P. curtula the father, the male and the female hybrid caterpillars, after the first molt, are markedly different. The difference involves the form, color and

marking of the two kinds of individuals. The male hybrid caterpillars are closely similar to the caterpillars of the maternal race (anachoreta), while the hybrid female caterpillars resemble those of the paternal race (curtula). The explanation of this result is apparent if the character differences are due to genes carried in the Z-chromosomes; for the daughter gets her single Z-chromosome from her father, which she resembles, while the son gets one from each parent. If now the maternal Z^a (anachoreta) carries a gene (or genes) dominant to the gene (or genes) in the Z^c of the father (curtula) the son will resemble the mother because *ex hypothesi* she carries the dominant gene or genes.



The reciprocal cross bears out this interpretation. Thus, if P. anachoreta is the father and P. curtula the mother, all the offspring are alike. In this case the daughter again gets her single gene Z^a (dominant) from her father, while the son gets this dominant gene (Z^a) from his father, but also the recessive gene (Z^c) from his mother. Here, then, the male and female are both alike because the female carries only the dominant chromosome and the male carries both—the dominant one determining his character. Thus:



The analysis is further borne out by back-crossing the hybrid male to one or the other parental races. (It was not possible to make an F_1 cross, owing to the sterility of the female hybrid.) Federley succeeded in making such crosses. The results can not be explained by the ordinary extension of the formula, because, as Federley showed, the usual reduction of the chromosomes at the maturation division does not occur in the male hybrid. On the contrary, the two sets of chromosomes in the hybrid divide (twice) and as a result each sperm carries the diploid number—one set of

maternal and one set of paternal. When these sperm fertilize the eggs of a female of either original stock (curtula or anachoreta) the resulting offspring are triploid. Nevertheless, the relation of dominance and recessiveness assumed for the first generation crosses will explain the observed results, provided two doses of the recessive gene (two chromosomes carrying these genes) do not affect the dominance of the other genes (the single chromosomes carrying these genes).

The caterpillars of some moths have two (or more) color forms in the later stages. Weismann ('76) had speculated as to the interpretation of these types. Federley ('16) reared green and dark caterpillars and mated the moths that came from them; green female to green male, green female to dark male, dark female to green male and dark female to dark male. All the offspring were dark caterpillars. The results show that the difference is not genetic but environmental. The external factor that causes the change was not discovered. On the other hand Gerould ('21) has recently discovered a new color type of the common clover butterfly (Colias philodice) that behaves in its inheritance as a Mendelian recessive. This is a blue-green caterpillar that arose as a mutant of the normal yellow-green type. As in several other mutant characters in silkworm moths this one also is connected with an alteration in the color of the blood. In the normal caterpillar of this species, the color of the blood makes the caterpillar yellow-green. Correspondingly, the blood of the mutant is blue-green and shines through the skin after the first molt. Poulton pointed out ('85 '93) that in plant-eating caterpillars one green pigment in the blood is derived, with only a little change, from the chlorophyll of the food plant. It is the way then in which this change is affected by the genetic make-up of the mutant caterpillar that makes the color of the blood different from that of the normal caterpillar.[2]

In the group of moths and butterflies the sex chromosomes are represented by the formula WZ ♀, ZZ ♂. In other groups of insects another formulation holds, namely, XX ♀ and XY ♂. Here sex-linked inheritance is the same in principle as in moths, if the X's carry the sex factors. There are many adult characters of insects that show this form of sex-linked inheritance, and there is one case at least of a larval character that is inherited in the same way. In the vinegar fly there is a race which carries in one of its X chromosomes a Mendelian factor that produces a tumor in the larva,

[2] Hein ('23) has recently found three types of larvae of the meal worm (*Tenebrio molitor*) whose heredity shows that they are represented by three allelomorphic genes. Tower ('10) has shown that two larval types of the beetle *Leptinotarsa signaticollis* are represented in the germ material by two Mendelian genes.

and any larva that develops this tumor dies. The inheritance of the tumor may be illustrated by an example. All females of the stock carry one lethal factor in one of the X chromosomes, the other chromosome carries the normal partner (allelomorph) of this factor, and since the normal factor is dominant the female has not perished in the larval stage. She produces two kinds of eggs after the extrusion of one or the other X in the polar bodies. One X carries the lethal factor for the tumor, the other X its normal partner. If the eggs of such a female are fertilized by the sperm of a normal male—half of whose sperm are X bearing, and half are Y bearing—four possible kinds of embryos are expected. If the lethal bearing egg is fertilized by the X sperm, a daughter like the mother is produced; if the egg bearing the normal X is fertilized by an X sperm, a normal daughter is produced. The former is like the mother and transmits to half of her offspring the lethal factor, the other daughter is entirely normal and never transmits this tumor. If the lethal bearing egg is fertilized by the Y sperm, the sons, so produced, die because each contains only the maternal X with its fatal contribution. If the other kind of egg (bearing the normal X) is fertilized by a Y sperm, a normal son is produced that does not transmit the tumor to any of its descendants. The sex ratio has been changed, owing to the death of half the sons. The result is two daughters to one son.

Sex Formulas

In the sex formulas that have been here used, the WZ–ZZ and the XX–XY types, the W chromosomes in the former and the Y chromosomes in the latter have been ignored because experience has shown that they carry no factors that affect the Mendelian results. It is not to be inferred that even in these types no factors whatever are carried by the chromosomes. It has, in fact, recently been shown that the heredity of certain adult characters can only be explained on the view that such factors are carried by the Y chromosome and certain results of Goldschmidt on the gypsy moth have also been accounted for by him on the assumption that the W chromosome carries certain Mendelian factors.

Thus it has been shown by Schmidt ('20) and confirmed by Winge ('22, '23) that in the fish Lebistes a character peculiar to the male is carried by the Y chromosome, or at least the inheritance of this character is explained if its distribution is the same as that of the Y chromosome. Since the Y chromosome never gets into the female line it follows that the gene is never carried by the female and is transmitted only from father to son. It differs from the other type of sex-linked inheritance in one important respect, since

in the XX–XY type the X chromosome is shuffled back and forth between the sexes.

Aida ('22) has also found in another fish Amplocheilus that certain characters are carried by the Y chromosome and both Winge and Aida show that crossing-over may take place between the Y and X chromosome. It would seem to follow if the sex mechanism depends on a constant relation between the X or the Y and the other chromosomes that crossing over between X and Y would soon make them alike and destroy their relation in the sex scheme. This would be true only if more than one sex factor exists in the sex chromosomes; for, if only one pair is present it might be shuffled back and forth indifferently without affecting sex since then that one of the two sex chromosomes that contained the Y gene would, by definition, become Y. It can only be surmised, in case there is more than one sex factor in the sex chromosomes, that crossing over would occur only in that part of the X that does not contain the sex factors. The failure to cross over might possibly be due to difference in length of the X and Y, or to some other relation interfering with crossing over in one end or in some part. The suggestion may not seem so fanciful if it is recalled that in Ascaris it has been found that the X chromosomes are attached to another pair of chromosomes, that would correspond therefore to the supposititious X and Y of the fish.

Heredity of Down Color of Chicks

The inheritance of the color of the down of newly hatched chicks presents some unique problems. The color of the down may be and generally is quite different from that of the adult fowl, yet a certain down color is associated with definite adult colors. In some races of poultry the color of the down is uniform or nearly so, while in other races there is a characteristic down-pattern that bears no obvious relation to the pattern of the adult bird. The inheritance of these characters has not been fully worked out, but enough has already been done by Bateson ('02) Bateson and Punnett ('06) Goodale ('09) and Punnett ('23) to show that the inheritance is Mendelian. A few typical cases may be given.

The down of the white breeds, whether the white is the dominant or the recessive, is yellowish. If a dominant white breed is crossed to a colored breed the down of the F_1 chicks is white, although it may be slightly ticked, *i.e.*, it may show a few colored down-feathers. If a recessive white is crossed to a colored race the chicks have colored down. The actual color may depend on the color factors carried by the recessive white if these factors are dominant to those of the P_1 colored breed.

Buff races have buff chicks; black races have black chicks; blue adults come from blue chicks. Chicks of the Brown Leghorn race and of Game Bantams, both of which races approximate to the wild type, Gallus Bankiva, are brown-striped, *i.e.*, they have a brown pattern on a buff background. Barred birds, such as Plymouth Rocks, have black chicks that is less intense than that of black breeds and they have also a yellowish-gray patch on the back of the head. Other "barred" races, such as the Gold Pencilled Hamburgs, have striped chicks that are less conspicuously striped, however, than are Brown Leghorn chicks. The striped chicks of another "barred" race, the Campine, have very wide stripes, etc.

The inheritance of these characters of the chick follows closely the kind of inheritance shown by the adult bird of the races to which they belong, and, for the most part at least, may be supposed to be due to the effects of the same color factors acting on younger stages in which their effect may be outwardly quite different from the effects of the same factors on the adult birds. However, the work has not progressed sufficiently far as yet to exclude the possibility that there may also be specific factors that affect primarily the color of the chick and to a less extent that of the adult.

When certain races are crossed, more particularly where one race is silver and the other gold, the inheritance is sex-linked and follows the same rule as that for sex-linked characters of moths. The female has one Z chromosome and the male two Z's that carry these contrasted characters. The chicks show the same kind of inheritance as the adults, and since the difference is apparent at hatching it enables the breeder to pick out at once the F_1 males from the females if a suitable cross has been made. Thus, according to Punnett, when a Light Sussex hen is bred to a Brown Leghorn cock the silver male chicks are markedly different from the gold female chicks.

Maternal Inheritance

There is a form of heredity sometimes called maternal inheritance which, while Mendelian in principle, yet shows certain features that have an important bearing on embryonic phenomena. If the eggs of a species of sea urchin, or fish, whose cleavages have a certain tempo are fertilized by sperm of another species having a different tempo the cleavage of the egg is still that of the maternal race, *i.e.*, it shows no effect of the sperm. Since this is true of the reciprocal cross also, the results are evidently not due to the dominance of one type but due to a property of the egg itself —a property that has been impressed on the protoplasm, as other results show, by the maternal chromosomes. Expressed in another

way the result means that the chromosomes brought in by the sperm have not had time to change the condition of the egg's protoplasm already induced by its own chromosomes. That this is really the explanation is shown by rearing later generations from the eggs that have shown maternal inheritance in the first generation. While this has not been done in the case of the sea urchin or the fish it has been carried out in other forms. The best known case of this sort is that of the silkworm moth where Toyama has shown that the color of an embryonic egg-coat, the chorion, follows the scheme of maternal inheritance. More recently Uda ('23) has published facts that may be interpreted to mean that the embryonic membrane, the serosa, that Toyama supposed also to be inherited as a maternal character is not inherited in this way.

One of the most interesting cases of maternal inheritance shown by silkworms relates to the number of broods per year. In some races there is only one generation a year (univoltine), in other races there are two generations. When such races as these are crossed the hatching of the egg is a function of the maternal race. The simplest explanation of this result is that it is due, in all likelihood, to some peculiarity of the egg-coat.

A striking case of maternal inheritance has recently come to light that bids fair to explain one of the outstanding puzzles of heredity.

In some species of snails, the shell and its contained viscera are coiled in a right spiral (dextral) in others in a left spiral (sinistral). It was shown by Crampton and by Kofoid ('94) that these two types can be distinguished as early as the second cleavage, and perhaps even at the first, by the form of the cleavage pattern—one is a mirror figure of the other. It was known from the observations of Mayor ('02) and of Crampton ('16) on Partula, and has been confirmed by the recent work of Boycott and Diver ('23) on Lymnaea, that all the offspring of a given brood are dextral or else sinistral. It has also been shown that some sinistral mothers produce only sinistral broods and that other sinistral mothers produce dextral broods. Conversely, some dextral mothers may produce only sinistral broods and other dextral mothers may produce dextral broods. These facts were very puzzling from a genetic standpoint, and there was no satisfactory explanation at hand. The recent extensive experiments of Boycott and Diver have supplied data which Sturtevant ('23) has shown can be interpreted, if the character of the cleavage (hence the character of the adult) is impressed on the egg by its genetic make-up before the maturation divisions have occurred. An example will serve to show the principle involved.

Suppose, as the evidence indicates, there is a dominant dextral

and a recessive sinistral factor carried by a given pair of chromosomes. A self-fertilizing dextral snail that is heterozygous for these factors (Ll) produces after maturation two kinds of eggs L and l. Similarly, there will be two kinds of sperm; namely, L and l. Self-fertilization will give three genetic types of offspring—LL, Ll and ll; but all these individuals will be dextral because the cleavage pattern has been already determined in the egg by the dominant factor L before the polar bodies were given off. Of these three types the first two LL and Ll will produce only dextral offspring, but the other type, ll, that has also a dextral shell will produce only sinistral offspring. Since these snails may also cross-fertilize, provided dextral mates to dextral, and sinistral to sinistral, it is possible for the dextral female (arising as above) with the genetic constitution ll to mate with a dextral with the composition LL. All the offspring of such a somatically dextral female will be sinistral, since the undivided egg was under the influence of the two recessive genes (ll). These sinistral snails (Ll) in turn will produce only dextral offspring because the dominant factor L in the egg determines the type of cleavage of the eggs. It is evident, therefore, that dextrals of certain origins will produce only sinistral broods and sinistral of certain origins dextral broods. The heredity is Mendelian, but the appearance of the character is delayed for a generation. The result is unique, because the symmetry of the individual is determined not by its own genetic constitution but by that of the unreduced egg from which it arose.

POLITICS AND SCIENCE

By Professor JOHN A. FAIRLIE

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Is there a science of politics or indeed of any of the social studies? If so, how may the field of investigation be defined and differentiated, and what are the postulates and methods and some of the laws or principles which have been established?

The term "political science" is an assertion or claim that there is such a science; but at the same time the use of the word "science" indicates at the outset that there is a special need for asserting that it is a science, which does not seem to exist in the case of other sciences, such as astronomy, physics, chemistry, geology, botany and zoology. Moreover, other terms, such as political philosophy and political theory, have also been used for studies in political institutions, which indicate that at least some students in this field distinguish their work from that of science.

It is true that the standard dictionaries define "politics" as both an art and a science; and one explanation for the term "political science" may be found in the general use of the term politics for the art or practice of government. Curiously, no one seems to have suggested the term "politology" for the science of politics, if such there be.

The existence of any science of politics has, however, been openly disputed by writers of standing. More generally, workers in the physical and biological sciences have appropriated the term science as applying only to their own group of studies, ignoring not only politics, but often also all the social studies. In some cases, where a comprehensive analysis and classification of the sciences has been made, there has been a grudging recognition of "sociology" as a prospective science in its early beginnings, with politics and economics noted as branches or applications of such a future science.

Thus Comte, in his "Positive Philosophy," denied the claim of politics to be ranked as a science, on the ground that: (1) there was no consensus of opinion among experts as to its methods, principles and conclusions; (2) it lacked continuity and development; and (3) it lacked the elements which constitute a basis of prevision.[1] So, too, John Stuart Mill wrote (in his "System of Logic," 1843):

[1] "Positive Philosophy" (1830–42). Eng. trans. by Martineau, ed. of 1893, Vol. II, Ch. 3.

It is accordingly but of yesterday that the concept of a political or social science has existed anywhere but in the mind of here and there an isolated thinker, generally very ill-prepared for the realization.

And Buckle, in his "History of Civilization" (1857), declared that "in the present state of knowledge, politics, so far from being a science, is one of the most backward of all the arts."[2]

Professor Sheldon Amos, author of one of the earliest works on "The Science of Politics," noted that objection to the study of politics as a science came from two radically opposing types of mind. Speculative minds "are discontented with the notion of a so-called science of politics" because of the complexity of the subject-matter, and the intrusion, at all points, of such seemingly incalculable factors as the will and passions of mankind. Practical statesmen, again, immersed in actual business, and oppressed by the ever-recurring presence of new emergencies, almost resent the notion of applying the comprehensive principles of science, and still more the conjectural use of foresight, in respect of subjects which, for them, are in ceaseless flux, and can, at best, only be safely and wisely handled "by momentarily adjusted contrivances." . . . "The aggregate result is that politics floats in the public mind either as a mere field for ingenious chicane or as a boundless waste for the evolution of scholastic phantasy."[3]

The prevailing attitude of those in the more clearly recognized physical and biological sciences may be indicated by the action of two leading organizations of such scientists in the United States. The American Association for the Advancement of Science, with an elaborate organization of sections for the various physical and biological studies, has but a single section on social and economic science, with no provision for students of politics. The National Research Council, whose name and authorized purposes indicates that it proposed to deal with all fields of research investigations, has been composed of physical and biological scientists and has announced that its work will be limited to such sciences, with no provision for research in the social studies.

The views of present-day physical and biological scientists are more definitely set forth in two recent brief but comprehensive analyses of the field of science. Professor J. A. Thomson, in his "Introduction to Science" (1911) lists "sociology" as one of the great fundamental sciences, of which politics, civics and economics

[2] Vol. I, p. 361.

[3] "The Science of Politics" (1883), p. 2. *Cf. The Times Literary Supplement*, August 31, 1922: "The art of the statesman is concerned with the possible, the practicable, the gradual. It has nothing to do with mathematical certainties and universalities, and still less with Utopias and Paradises."

are but applications; and of sociology he states that it "is still a very young science."[4] Professor du Sablon, in his "L'Unité de la Science" (1919) gives one chapter of 17 pages (out of 280) to the "moral sciences," including ethics and social studies, and concludes that "the moral sciences are much less advanced than the biological or the physical sciences. We see them still in the descriptive period, where the phenomena are observed without always knowing their causes and without being able to establish their laws."[5]

Before considering what may be said of politics as a science on behalf of those who have given serious attention to the study of this subject, we may turn to recognized scientists for a definition of science, and a statement of its distinctive methods, by which the claims of politics may be tested.

In his "Grammar of Science," Karl Pearson states that "the classification of facts, the recognition of their sequence and relative significance is the function of science." Professor J. A. Thomson defines science as "criticised, systematized and generalized knowledge." He also summarizes his discussion of scientific method in these words:

> The first step in scientific procedure is to collect data, and all science begins with measurement. The second step is the arrangement and classification of facts. Auxiliary to this and to formulation is the process of analysis or reduction to simpler terms . . . it is often necessary to try one hypothesis after another. An important step in the procedure is the carrying out of test experiments. The final result is a general formula or law of Nature, or more frequently the inclusion of a new set of facts within an old law.[6]

Professor du Sablon carries the scientific process beyond Thomson's final step. Concluding his study on the unity of the sciences, he states:

> All the sciences develop in the same way. The point of departure is furnished by the direct observation of nature; the induction leads to a series of laws which are only the generalized expression of the phenomena; finally, experimental science is encompassed by a theory in which the laws and phenomena are deduced from certain principles laid down *a priori*. The methods successively employed are then: experience, induction, deduction.

[4] In Home University Library, Ch. 4, p. 107.

[5] P. 270.

[6] "Introduction to Science," pp. 79–80. In the more recent "Outline of Science" (Vol. 4, p. 1169) Professor Thomson states that: "Science includes all knowledge, communicable and verifiable, which is reached by methodical observation and experiment, and admits of concise, consistent and connected formulation." The methods of science, he adds, are: first, to get the facts by observation; second, accurate registration of the facts; third, arranging the data in workable form; fourth, finding a law or formula for uniformities.

If the definitions given above are accepted, it can hardly be denied that there have been from early times a scientific study of politics by the systematic analysis and classification of facts leading to generalizations. There have also been theoretical, speculative and imaginative writers on political subjects, from Plato in his "Republic," to More's "Utopia" and Bellamy's "Looking Backward," whose works have not been closely related to the systematic study of the facts of political experience, and can not well be claimed as scientific. But the scientific work of Aristotle in the field of politics was more thorough than in the natural sciences, and he considered politics as the "master science."[7] With him may be classed other less important writers of ancient times, such as Polybius and Cicero; and in later times there are such outstanding names as Machiavelli (who is said to have "founded the science of politics for the modern world by concentrating thought upon the fundamental principles"),[8] Bodin, Hobbes, Montesquieu and Madison.

It may, indeed, be said that at the end of the eighteenth century the science of politics was further advanced than the physical and biological sciences. But, with the marvelous development of these other sciences in the nineteenth century, politics and other social studies seem to have at least relatively lost ground; and it is in view of the recent achievement of the natural sciences that the social studies have come to be considered as in a backward stage, if they are to be admitted as having at all the status of a science as the term is used at the present time.

Nevertheless, it may be shown that the scientific study of politics, and also of other social studies, has made substantial progress during the past century. In the middle nineteenth century, Comte, Buckle and John Stuart Mill (whose deprecatory statements about the status of politics as a science have been noted) each made notable contributions. Of the many later workers in this field, mention may be made of such important figures as Sir George Cornwall Lewis, Henry Sidgwick and James Bryce (in Great Britain), Bluntschli and Jellinek (in Germany), de Tocqueville (in France), and (in the United States) Francis Lieber, Theodore Woolsey, John W. Burgess, Jesse Macy, W. W. Willoughby and F. J. Goodnow.

[7] *Cf.* E. Barker, "The Political Thought of Plato and Aristotle," pp. 10, 237–241.

[8] Encyclopedia Britannica (9th ed.), XV, 150. Bodin is said to have given system to the modern science of politics by his definition of sovereignty. David Hume in an essay entitled, "That politics may be reduced to a science," asserted that: "So great is the force of laws and of particular forms of government, and so little dependence have they on the humours and tempers of men, that consequences almost as general and certain may sometimes be deduced from them as any which the mathematical sciences will afford us."

The mention of such writers on political institutions and their works is of service, as was noted by Professor Amos, forty years ago, "first, as substantiating the truth that there is a veritable science of politics, and then as illustrating the special difficulties which the cultivation of that science has to contend with." The same writer, after analyzing the objections and obstacles to the development of a complete science of politics, also noted the indications that the study of politics was "being placed on a platform of far higher scientific exactness than ever before" and came to the conclusion that "the scientific method in politics, as elsewhere, is slowly and surely getting the better of the empiric."[9]

About the same time Sir Frederic Pollock, in his lectures on the "History of the science of politics," maintained that "there is a science of politics in the same sense, and to the same, or about the same, extent, as there is a science of morals." He added, further, that "political science must and does exist, if it were only for the refutation of absurd political theories and projects."[10]

That a considerable advance in the study of politics has been made since these modest statements were made may be indicated by the views, still conservatively expressed, of one who will be recognized as a leading figure in that advance, and whose work in this field may well be compared to that of Darwin in biology. In his annual address as president of the American Political Science Association in 1908, the late James Bryce undertook to say of political science, "What sort of a science is it?" Granting that it is not an exact science, such as mathematics, physics or mechanics, and admitting that the data of politics can not be weighed with the precision of natural phenomena, he took the position that

> in calling politics a science we mean . . . that there is a constancy and uniformity in the tendencies of human nature which enables us to regard the acts of men at one time as due to the same causes which have governed their acts at previous times. Acts can be grouped and connected, can be arranged and studied, as being the results of the same generally operative tendencies.

He also maintained that "it is not a deductive science any more than it is a branch of speculative philosophy," but was found on the systematic analysis of historical facts. Further, he added:

> It is an experimental science, for though it can not try experiments it can study them and note results. It is a progressive science, for every year's experience adds not only to our materials but to our comprehension of the laws that govern human society.[11]

[9] "The Science of Politics," pp. 17–21.

[10] Pp. 2–4.

[11] *American Political Science Review*, III, 1–19 (1909).

The status of politics as a science may be further examined by considering its postulates and methods of procedure, and noting how far they correspond to or differ from those of other sciences.

As to postulates, the student of politics, as of the physical sciences, accepts as established for his purposes by common experience the existence of a world of conscious persons and of things; but with considerable difference of emphasis and importance for his investigations.[12] The nature and characteristics of impersonal things, whether animate or inanimate, is not a direct object of inquiry in politics; in such matters the established results of other sciences are accepted, though the study of groups of animals is of direct interest to the investigation of social institutions, and some analysis and comparisons can be made to political institutions.

On the other hand, in politics and all the social studies, the nature and characteristics of human persons are of greater importance than in the physical and biological sciences, except in psychology, if that is included with the latter group. In the social studies, as in all science, the student and investigator is a person whose characteristics have much to do with his inquiries and their results; and the existence of other persons making similar inquiries is recognized and accepted. But, in addition, the object of inquiry is also the great body of human persons, including the investigator and his colleagues, with special reference to their actions in connection with their fellows which differentiate them from impersonal objects.

Politics, as distinguished from other social studies, deals with the life of men as organized under government and law, in what is known as the state. It includes a study of the organization and the activities of states, and of the principles and ideals which underlie political organization and activities. It considers the problems of adjusting political authority to individual liberty, the relations among men which are controlled by the state and the relations of men to the state. It also deals with the distribution of governing power among the several agencies by which the actions of the state are determined, expressed and executed, and with the political problems of international life. As a science, it aims to furnish a basis of accurate information and intelligent opinion, in place of emotions and prejudices, for forming judgments in public affairs; and it seeks to develop a sense of the rights and responsibilities of citizens and an understanding of the significance of law. As its distinctive contribution to the social studies, it lays emphasis on

[12] These postulates may be contrasted with those of President Woolsey in his treatise on "Political Science," published in 1878. "We assume the personality and responsibility of man as a free moral being. We assume also a moral order of the world. . . . We discard the greatest happiness theory. . . . We hold also, most firmly, to a system of final causes."

law as a means of social control and on governmental action for the promotion of general welfare.

The methodology of political science has been discussed by a number of writers. Comte considered that there were three principal methods for the scientific study of social phenomena—observation, experiment and comparison. These are well-recognized scientific methods, and with these may be considered the employment of statistical data as a means of measurement. To these, there may be added the method of subjective introspection, and, as in all scientific inquiries, the process of reasoning from the data forms an important stage in leading to conclusions.

Comte noted further the historical method in social investigation, to be applied only in dealing with the most complex phenomena. But this term seems to belong to another category from those noted above—including juristic, biological, psychological and sociological. These terms, however, do not indicate so much methods of investigation as points of view from which political and social institutions may be studied, suggesting the application of methods employed in these other fields of inquiry.

Still other terms are particular aspects or subdivisions of a general procedure rather than distinct methods.

Those who undertake the study of politics as a science, as distinguished from those who are mainly concerned with matters of theory and speculation, take for their starting point the observation and examination of political phenomena. It must be recognized, however, that the extent to which any single investigator can make direct personal observations of the widely scattered political phenomena is closely limited. It is a very exceptional case where one man can cover even a considerable fraction of the ground traversed by James Bryce, travelling for threescore years in all parts of the world. Even Mr. Bryce secured much of his data from others. Most students must depend even more largely on official records and on the reports of other direct observers; and allowances must often be made for the aberrations and refractions of these telescopes and microscopes of the political investigator. So, too, the student in other scientific fields does and must depend on and accept to a large degree the results of others. The trained observer can recognize and segregate doubtful items, and base his further study on acceptable data. But better work could be done, if larger provision was made for more direct observation by men of scientific training.

The place of experiment in political science has been much discussed and its validity has been openly questioned. Sir George Cornwall Lewis held that:

If by an experimental science, we mean a science which admits of scientific experiments, of *experimenta lucifera*, then politics is not an experimental science; but if we mean a science founded on observation and experience, politics is an experimental science.[13] . . . We can not do in politics what the experimenter does in chemistry. . . . He may isolate the phenomenon with which he deals and expose it to certain selected influences, leaving the surrounding medium unchanged. But if the political scientist wishes to experiment with democracy, for instance, he can not select a state at will, introduce his democracy and wait for determinate results. He will find himself powerless to exclude extraneous influences, such, for example, as panics, commercial crises, insurrections or other happenings, which might destroy the results of the experiment.

John Stuart Mill, in his *Logic*, also considered real experiments in politics to be impossible. And Sheldon Amos, in his "Science of Politics," referring to Mill and emphasizing the importance of repetitions with exactly estimated variations for a true experiment, urged that on account of human personality and the influence of the past on the future, no combination of circumstances can be repeated once, let alone often.[14]

It must be recognized, as John Adams observed, that "a political experiment can not be made in a laboratory, nor determined in a few hours." But experiments may be made outside of a laboratory, and while the phenomena of politics may not be so thoroughly isolated nor subject to as large a measure of control as in the laboratory, it remains true, as was noted by William James, that "nonisolable elements may be discriminated provided their concomitants change."

Indeed, it may be said that governments are continually trying experiments on the community. Every new law, every new institution, every new policy is to some degree experimental.[15] Most of them are modified to meet the needs indicated by experience; and some are quickly repealed or abandoned after a short trial. Bryce, in his "American Commonwealth," pointed out as one of the merits of our federal system of government that "it enables a people to try experiments in legislation and administration which could not be tried in a large centralized country."[16]

But while novel schemes are frequently tried in modern governments, the observation and critical examination of the results are too often inadequately carried on, and the value of the experiment

[13] "Methods of Observation and Reasoning in Politics," I, 178.

[14] Amos, "Science of Politics," p. 113. Bryce, in "Modern Democracies" (Ch. 2), notes that: "Experiments in physics can be tried over and over again until a conclusive result is reached, but that which we call an experiment in politics can never be repeated because the conditions can never be exactly reproduced"; as Heraclitus says, "one can not step twice in the same river."

[15] Garner, "Introduction to Political Science," p. 23.

[16] Third Ed., Vol. I, Ch. 30, p. 353.

may be largely or wholly lost. The direct primary has been introduced in many states in this country, and legislation by initiative petition and referendum in a number. Both of these devices have been in use for a considerable period of years. Both are still eagerly supported and bitterly denounced. But there has been as yet no comprehensive attempt at a scientific examination of the results; and the general opinion is affected largely by a few particular instances which happen to attract attention. This, however, is not because students of politics are not able to undertake such investigations; but to the lack of the means for scientific research on such political problems to the same extent as they are furnished in the case of an expedition to Crocker land or the South Pole or studies in astrophysics.

The limitations on political experiments do not, however, prevent the scientific study of politics. In the most exact of the physical sciences, that of astronomy, experiments are impossible; and in geology, the collection of data in field studies is less subject to control than in the case of political phenomena.

The method of comparison comprehends a variety of processes, such as the arrangement of data, its classification, coordination and elimination.[17] It includes what is sometimes referred to as a distinct "historical" method, for this involves a comparison of institutions and conditions at different periods, which is as important for the student of politics, as is the life history of a plant or animal to the biologist. Such historical studies also serve to emphasize the elements of continuity and development in political institutions. As was said by Professor Seely, "History without politics has no fruit. Politics without history has no root." Or, as stated by a French writer (M. Deslandres), "History is the solid element without which political science would only be fragile and hazardous."[18]

But the comparative method in the study of politics embraces more than the historical study of one political system. It involves a comprehensive examination of different systems, in different countries, and under different conditions. By comparing points of difference and agreement, a basis can be found for comparing the results of varying factors; though the complex plurality of factors add to the difficulties of tracing the results of any one.

To quote Bryce again:

> That which entitles it (the comparative method) to be called scientific is that it reaches general conclusions by tracing similar results to similar causes, eliminating those disturbing influences, which, present in one country and absent in another, make the results in the examined cases different in some points while similar in others.[19]

[17] Garner, *op. cit.*, p. 22.

[18] Quoted by Garner, *op. cit.*, p. 29.

[19] "Modern Democracies," Ch. 2.

There has been a marked development during the recent decades in the scope and character of data and the intensity of inquiries as the basis for the study of politics. Until after the middle of the nineteenth century most of the writers on politics gave little attention to the detailed investigation of data, and their writings were largely legalistic deductions based on *a priori* generalizations. Then attention was given to historical records and the comparison of official documents and legal institutions. In the latter part of the century Mr. Bryce led the way to a much broader scope of personal observation, including the examination of legislative procedure, political parties and other extra-legal practices and customs, in what President Lowell has called the physiology of politics.

Developments may also be noted in the attention given to various factors affecting political conditions and to the influence of analogies from other fields of study. Thus, for a time environmental conditions occupied the foreground, with varying emphasis on physical and geographical, economic and social conditions. With the progress of biology more consideration was given to the influence of heredity, racial characteristics, the organic view of political and social organization and the idea of progressive evolution.

Nevertheless, until the end of the last century most students of political problems obviously avoided the application of standards of quantitative measurement in their work; and thus seemed to acknowledge that their studies lacked what has been said to be the first essential of scientific procedure. As already noted, Lord Bryce frankly stated his belief that political data could not be measured with precision, and that politics, therefore, could not be considered an exact science. His own work shows the influence of this view, in his avoidance of statistical and other numerical data; though this may have been at least partly due to the literary character of his writings, which appealed to a wide audience, and avoided the technical analysis of the professional scholar.

It may be recognized that much of the statistical data used in discussions of political and social subjects is far from complete and is sometimes based on rough estimates; and also that many political phenomena have not, at least as yet, been reduced to precise measurement, though in some directions the psychologists seem to be making some advance in this matter.

It can be urged, however, that there is a large body of reliable numerical data as to political and governmental action available for scientific analysis, and that much more could readily be secured in the scattered records of public offices with much less difficulty and expense than that which is met in securing their primary data by students of the physical and biological sciences. As illustrations

may be cited election statistics, the records of the financial transactions and the activities of public officials, and the proceedings of legislative bodies.

The Belgian statistician Quetelet (1796–1874) made the first important use of statistical methods in the study of social phenomena, by applications of the theory of probability, in "Sur l'homme et le development de ses facultés" (1835). More recently President Lowell has shown how effective and scientific use can be made of political statistics in his analyses of voting in legislative assemblies (in his "Government of England"), and of popular voting on constitutional and legislative measures (in his "Public Opinion and Popular Government").

Within the last twenty years, there has been a considerable development of more systematically organized research work in politics, and other social studies, based largely on statistical and other measurable data. On a small scale, some work of this kind has been done by legislative and municipal reference bureaus; and more important studies have been made by some of the numerous temporary commissions and permanent administrative agencies, on such subjects as education, taxation and administrative organization. There have also been organized a considerable number of bureaus of governmental research, supported by private funds, for the intensive study of governmental conditions. Much of the work of these bureaus has been done by engineers and accountants, making use of statistical data. Applications of statistics in other fields, such as anthropology and psychology, have also dealt with problems of political interest.

But what has been done in these directions has barely scratched the surface, and the possible scope of such studies is almost unlimited, if resources can be secured for collecting the data and for its critical examination by competent students.

In one respect the study of politics and of the other social sciences can hardly avoid recognizing a factor which is not so clearly recognized in the physical and biological sciences; and this makes possible, if not necessary, one method or process not openly utilized in these other sciences. The study of political and social action involves some ideas as to the character of what is called human nature, and more particularly as to the characteristics of the human mind. But this is, of course, the field of psychology, and with reference to collective groups more especially of social psychology. The political scientist must, therefore, have some notion as to psychological principles, either by accepting those of the psychologists in so far as these are established, or undertaking inquiries in this field for himself.

Such a study of human nature or the human mind, as related to political and social action, might be undertaken as an objective study, as by the behavioristic psychologists. But inasmuch as the political and social investigator is himself one of the human beings whose conduct is being considered, it is possible to make, and indeed difficult to avoid making, some judgment as to the mental processes affecting human conduct by subjective consideration of what at least seems to go on in the investigator's own mind. And until the behavioristic psychologists can furnish a reasonably adequate explanation of mental processes on an objective basis, the method of subjective introspection not only can but probably must be recognized by the student of politics as a factor in reaching his conclusions.

It may be admitted that this method is as yet less accurate and reliable in securing uniform or closely similar results than the observations and laboratory experiments of physics and chemistry, though the latter are coming to be more clearly recognized as close approximations rather than absolutely exact formulations. But, if employed, not merely in a haphazard way by isolated individuals, but in a systematic and cooperative manner by a considerable number of careful students, as a means of interpreting the observed action of political and social groups, it may well be accepted as furnishing a basis for at least tentative opinions on questions not capable of determination merely by observation and comparison.

Such cooperative and systematic use of the method of subjective introspection can not be said to have developed to any large extent, and for this reason, the casual reflection and judgment of individuals still lack a good deal as a satisfactory basis for scientific judgments. Even such an experienced and careful student of politics as Lord Bryce, in postulating what seems to be a substantial uniformity of human nature,[20] has made an assumption, which (while simplifying the problem) is probably inadequate. There is need for further study as to the stability and changeability of human nature. Important recent studies in this direction are those of Graham Wallas in his "Human Nature and Politics" and "The Great Society," the recent analysis of the processes of formulating "Public Opinion," by Walter Lippmann and Dewey's "Human Nature and Conduct."

[20] " . . . there is in the phenomena of human society one "Constant," one element or factor which is practically always the same, and, therefore, the basis of practically all the so-called "Social Sciences." This is Human Nature itself. . . . Human nature is the basic and ever-present element in the endless flux of social and political phenomena which enables general principles to be determined. . . . Politics accordingly has its roots in Psychology." "Modern Democracies," Ch. 2.

The varying results and the slight development of a systematic application of subjective analysis may explain in part the retardation in the development of politics and other social studies on a scientific basis. But it may be submitted that the recognized and systematic use of this additional process should add rather than detract from the scientific character of these studies. It may also be suggested that, even in the physical and biological sciences, the mental reactions of the investigators are important factors in reaching their results; and the analysis of their methods is inadequate until such factors are recognized and considered.[21]

The scientific study of politics, as of other sciences, also requires the process of reasoning. As stated by Professor Seeley, "We must think, reason, generalize, define and distinguish; we must also collect, authenticate and investigate. If we neglect the first process, we shall accumulate facts to little purpose, because we shall have no test to distinguish facts which are important from those which are unimportant; and of course if we neglect the second process, our reasonings will be baseless and we shall but weave scholastic cobwebs."[22]

There have been, as already noted, many writers on political subjects, whose reasoning has been speculative and theoretical, though even some of these may have been influenced by observation and comparison. Other more scientific students of politics, whose discussions are related to the facts of observation, have differed as to their use of different methods of reasoning; and have been classified in different groups or schools.

One group of writers, both in Europe and America, have followed what has been called the juristic method. Of English writers, John Austin is notable for his application of deductive legal analysis to political problems. According to Professor Jellinek, formerly of Strasbourg University, this method aims to "determine the contents of the rules of public law and to deduce from them the conclusions to which they lead." In America, students and writers on constitutional and other branches of public law base their work largely on judicial opinions and legal reasoning, and some at least have applied these methods to the consideration of political problems not clearly legal in character.

But legal and judicial reasoning is not all of one type. Professor John H. Gray, of the Harvard Law School, writes in his lectures on the "Nature and science of the law," that there have been three leading methods of approaching the study of jurisprudence

[21] Professor J. A. Thomson states that: "Science is not so objective as it is sometimes supposed; we can no more escape from anthropomorphism than from our shadow." "The Outline of Science," IV, 1168.

[22] "Introduction to Political Science," p. 19.

—the analytical, the historical and the deontological, and that some writers have used all three methods. Dean Roscoe Pound, in his recent "Introduction to the Philosophy of Law," after tracing the methods of legal thinking from early times—Greek, Roman, the scholastic jurists of later medieval times, and the natural law writers—notes in the nineteenth century four well-marked types: First, an American variation of natural law, as deduced from American institutions; second, a metaphysical-historical method developed first in continental Europe; third, the utilitarian-analytic method, in England and the United States; and fourth, at the end of the century, a method of positivist sociological thinking, with a revival of natural law in terms of social utility.

Still another view of legal reasoning is presented in an article recently published, holding that lawyers and judges have been applying the methods of behavioristic psychology.[23]

All these methods of juristic reasoning are also applicable to the study of political institutions. They may be considered as variations and combinations of the primary classification into deductive and inductive logic; and the decided tendency of the recent scientific students of politics is away from the exclusively deductive logic of the analytic and deontological (or ethical) writers, towards the joint use of the inductive and deductive methods, characteristic of the historical and still more of the sociological writers, as it is also of the physical and biological sciences.

Political writers of to-day not only supplement the purely deductive logic of the analytical jurists, but they clearly go beyond the study of legal institutions and forms, to include the consideration of extra legal factors, social and political, which underlie the formal legal organization of the government and control many of its actions.

Students of political conditions also illustrate and reflect the varying tendencies of philosophical discussion, and in some cases have anticipated changes in their methods. The juristic analysts of law and politics may be compared to the absolute monists of philosophy, in seeking a single, indivisible principle behind the complex phenomena. But there are also political pluralists and pragmatists; and in recent years these have been active in their interpretations and in proposing new solutions of political problems. So, too, the doctrine of the relativity of political institutions to varying conditions has tended to replace the former views of absolute standards for all times and peoples.

In the discussion of political and other social problems, there are greater difficulties in the use of language than in the physical and

[23] *Journal of the American Bar Association*, Dec., 1922.

biological sciences.[24] The terms of politics and social affairs are not of a specialized technical character; but are, for the most part, words in common use, with vague and varying shades of meaning. This variety is further increased by the popular and literary discussion of such problems, with little effort at, and even less success in, the accurate presentation of the data and the conclusions. Moreover, a considerable number of terms employed have acquired emotional and ethical connotations, which arouse feelings of approval and disapproval, and retard efforts at an unimpassioned logical discussion. The word "politics" is itself one of the most striking illustrations of this uncertainty of meaning. Some others which may be noted are democracy, American, Prussian, Puritan, etc.

It is true that in legal phraseology words are used with more precise and technical meanings. But the legal meanings are often different from the popular; and in some cases the student of politics finds need for terms in a more definite sense than that of popular use, but in some respects different from the technical legal meaning.

Perhaps this difficulty is to some extent responsible for the efforts of some sociologists to develop a distinctive technical terminology for their field, with the result, however, of increasing the complexity of the situation.

Political science and the other social sciences have not in recent times formulated laws of human action in such simple terms and mathematical formulas as the laws of astronomy, physics or chemistry, so as to enable accurate predictions to be made as to future actions or the results of particular acts of the government. Indeed, in this respect, the present-day student of politics and other social conditions is more cautious than those of former times. In the past, there have been formulated periodic cycles of political and social changes, and at the end of the eighteenth century such dogmas as the equality of man and of states, the social contract, the separation of powers and the balance of powers in international relations, were widely accepted by political writers, and formally established in constitutions as the legal basis of political institutions. Some of these legal formulas to-day hamper political development, but the scientific student has understood for a good while that they are not precise statements of universal truths. In somewhat the same way, present-day scientists in other fields are learning that some of the simple mathematical formulas previously accepted are but approximations, satisfactory for working purposes under certain condi-

[24] *Cf.* President Lowell's remark that the study of politics "lacks the first essential of a modern science—a nomenclature incomprehensible to educated men." Presidential Address, *American Political Science Review*, IV, 1.

tions; but that more complex and involved equations must be worked out to meet a wider range of conditions.

But if some of the older formulas are no longer accepted as accurate and complete, the study of politics and social life leads, as in the case of the physical sciences, to the framing and acceptance of general propositions which indicate the results of certain kinds of actions. These propositions in all the social studies are less definite than those of the physical sciences. They show tendencies which may be offset by other factors, some of which may be recognized, though not even roughly measured, while others may not be clearly identified.

Of the social studies, the generalizations of economics are the most definite; and such "laws" as those of supply and demand, diminishing returns, the Malthusian law of population and Gresham's law of competing currencies are stated with a good deal of precision, and in some cases can be expressed or applied in mathematical terms.

Legal science, the oldest of the social studies, has also general principles underlying the manifold specific rules of law. The principle of order has been said to be the most fundamental; and the reciprocal correlation of legal rights and duties is also among the most important.

In the field of politics generalizations rarely, if ever, in these days, take the form of definitely formulated "laws." But a considerable number of tendencies can be observed and described, and some of the results of certain political actions can be forecasted with reasonable accuracy.

If we trace political development from the time of the Greeks, we can see: (1) the abolition of human slavery and to that extent the establishment of the principle of human freedom; (2) the general adoption of the principle of representative popular government; (3) the clarification of the doctrine of legal sovereignty in the political system; (4) the more recent recognition of the distinction between the political state and society; and (5) the success of the federal principle as a basis of governmental organization.

Among the later adjustments, we may note that, if the social contract is no longer accepted as the basis of government, it is more clearly recognized that all governments derive not only their just powers, but all their powers from the consent of the governed;[25] and the present tendency is to replace tacit consent by a more posi-

[25] "Even where there is an absolute monarchy, this is so. The king may claim to rule as of divine right. . . . But even so, the acceptance of the command depends on the faith of man in the divinity of its origin. Such a faith is only a form of general opinion, however important it may be, and so back to its foundation in general opinion the basis of sovereignty is always brought." Haldane, "The Reign of Relativity," Ch. 7.

tively expressed assent. So, too, if the eighteenth century doctrine of the separation of powers is no longer considered as essential to political liberty, it is more widely accepted that no one can be safely trusted to be impartial in his own case, and the importance of an independent judiciary is more actively urged.

In place of the three dimensional scheme of governmental powers, recent writers on politics, like the modern mathematicians, discuss four or five (or more) dimensions or categories of governmental functions. Political and social communities exhibit forces of attraction and repulsion, which vary, not only with their size and distance from each other, but also, as in the case of chemical affinities, with the internal characteristics of the several components. The psychological factor of fatigue is seen to be applicable to political activities, so that popular control of government may be weakened by requiring the voter to do too much.

In some respects changes in the generalizations of political thinking have been clearly affected by developments in the physical and biological sciences. The nineteenth century doctrines of the separation of powers and *laissez faire* individualism were related to a view of political and social organization based on Newtonian physics, in which the individuals were considered as somewhat like planets in the solar system. The later and equally dogmatic doctrine of Socialism has been related to the organic theory of political and social institutions, based on biology, in which the individual is considered as a cell in the larger organism of the social group or the political state.

To-day students of political and social affairs find both of these analogies unsatisfactory. Individuals in political and social communities are more closely related than the planets in the solar system; but they are not so completely absorbed in the larger groups as are the cells in a biological organism. In one respect, the social group seems clearly differentiated from the compound entities in the physical and biological sciences, in that the human individual (unlike the atom or the cell) may be and often is at the same time a member of a number of such social groups.[26]

[26] In a stimulating brochure, recently published, entitled "Des Sciences Physiques aux Sciences Morales," in which he has undertaken to demonstrate the application of mathematical methods to the moral as to the physical sciences, M. Jacques Rueff suggests the view that individualistic political economy may be compared to euclidean mathematics, applicable to practical conditions, while socialism he considers as a non-euclidean political economy, logically consistent with its own postulates, but not so convenient for the practical world of to-day. The general purpose of M. Rueff may be commended, but his applications are open to question. His analysis assumes that individualism and socialism are based on independent and contradictory assumptions. But at

An important problem in the psychology of the political and social group is that as to the nature of the general will or public opinion of the group, and this problem is also met in the legal discussions as to the juristic personality of corporations. Is there a real will or personality of the group, which is something more than the aggregate of individual wills and personalities? Whatever the answer is, it at least seems clear that the group or corporate personality does not completely absorb that of the individual members; and that the personality of the group is not more highly developed, but is less complete than that of at least some of the individual members.

If we turn from such limited generalizations, which have some analogy to the laws of physical sciences to more comprehensive hypotheses, such as M. Du Sablon considers the most important achievements of science, it may be of interest to note an instance where a student of politics seems to have anticipated by nearly half a century ideas recently presented as novel by present-day physical scientists and philosophers.

Fifty years ago, Walter Bagehot, an acute observer and writer on politics and economics, in his well-known work on "Physics and Politics," in which he applied some of the methods of scientific reasoning to political phenomena, undertook an analysis of the conditions underlying political and social progress. He noted as the first of these conditions the need for fixed and stable customs, developing into law; but that this stage of fixed custom must be supplemented by elements of change resulting from the original inventiveness of man. "Success in life, then, depends . . . more than anything else on animated moderation; on a certain continuation of energy of mind and balance of mind, hard to attain and harder to keep."[27]

This combination of stability and variety may be compared with

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least some students of social problems hold that the individual and society are but two aspects (or shall we say dimensions?) of the same phenomena; and combine them in one correlated system. On another basis it may be suggested that both individualism and socialism may be classed as sub-euclidean systems, based on not more than two dimensions; since both assume human nature as moving only in the one plane of logical reasoning. A more comprehensive science would seem to call for a recognition of emotions as a basis of human action, to form a workable euclidean three dimensional system. Perhaps other factors might also be considered as a basis for super-euclidean systems of social science.

[27] Or as stated by a recent writer: "The double law of politics is that sitting still is commonly wrong and forcing the pace is commonly disastrous." *Times Literary Supplement*, Aug. 31, 1922.

the views of Lawrence J. Henderson, a biological chemist, in his "Order of Nature" (1918), where he discovers the underlying condition of progress or evolution in the world of matter in the great variety of relatively stable compounds made possible by the characteristics of the more common chemical elements—oxygen, hydrogen, carbon and nitrogen. So too, in the field of biology, the evolution of species is ascribed to variations and mutations from stable inherited factors.

It may also be compared with the thesis of Professor Dewey, in his "Human Nature and Conduct," in which he finds the underlying factors of human character to be those of fixed habit and original impulse, and that improvement is to come through the intelligent correlation of these factors of stability and change.

Custom and initiative, stability and variety, habit and impulse, law and liberty—are these not varying expressions of the same fundamental paradox of the universe?

We seem to-day to be living in a time of radical, if not revolutionary, change. The indivisible and stable atom has been disintegrated and resolved into impulsive electrons. The foundations of physics have been shaken; and even the adequacy of euclidean three dimensional space is challenged by the doctrine of relativity.

So too, in the world of public affairs, the old order of stable custom has been thrown into confusion by the explosive impulse of war and revolution; and the whirling chaos of political electrons is seeking, though but slowly attaining, a new stability, with a larger synthesis in the League of Nations. In our own country, where the congealing habits of political institutions were but slightly melted by the heat of the distant explosion, the demand for normalcy has shown a tendency to return to the former status detached from the new world order. But it may be hoped that in the reaction from the chaos of Europe our political system may not become so petrified that another catastrophic explosion will be required to permit further development.

Under these circumstances, it is not surprising that recent writers on political problems have been less sanguine as to a general tendency to progress in human affairs. Even before the World War, Henry Adams, accepting the second law of thermodynamics as more firmly established by physical science than the doctrine of progressive evolution, had found the same degradation of energy in the history of civilization since the thirteenth century.[28] In the last volume of his comprehensive "History of Political Theories," Professor William A. Dunning, while recognizing developments in

[28] "Letter to the teachers of history" (1910), published in "The Degradation of the Democratic Dogma" (1919).

political institutions, could find, in the solutions proposed for the fundamental political problem of the basis of authority, no advance in the essential ideas beyond those of Greek thought. Lord Bryce, in his monumental work on "Modern Democracies," also strikes a note of disappointment as to the results of the democratic movement of the nineteenth century, though retaining a gleam of hope for the future.

In conclusion, however, we may say that there is a science of politics which, like other sciences, begins with certain accepted postulates, and by means of observation, experiment, comparison, subjective analysis and reasoning, has reached from time to time certain relatively stable principles; but that under the impulse of new facts and new ideas these principles are subject to modification and at times to sweeping changes. Whether such variations are all in the direction of progress, it may at least be said that they are signs of life, and that without them politics, and other sciences, would have reached the perfect stability of death.

THE DOG AS A DETECTIVE

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I

BEFORE the abolition of slavery in this country, dogs were much used in tracking runaway slaves; and as the dogs were so much used for this purpose, it was but natural that they came to be employed also in tracking and searching out criminals and other persons who were wanted by the police. And it became the practice in American courts, a practice which still exists in most of our states, to admit as evidence the statements of witnesses as to what a "bloodhound" has done in tracking an accused party. The employment of the so-called "bloodhounds"—many of which were really foxhounds or dogs of other breeds—declined after the abolition of slavery. But in the present century the utilization of dogs in the criminal service has received a new impetus from the movement to introduce police dogs into the United States, following the precedent of the systems of dog police in Belgium and Germany and other parts of Europe. The police dogs are truly useful in a great variety of services, and we hope to see them tried out and put into actual practice in this country, on a much larger scale than has yet been attempted. But the employment of dogs as detectives and the acceptance of their behavior as evidence that may lead to the conviction of a suspected person is so serious an undertaking that it should be permitted only on condition that we have full and accurate knowledge as to the capacities and limitations of the dog detective.

The fact is that the achievements of dogs in detective work have been greatly exaggerated. This conclusion has been reached as a result of experience with the canine police in actual practice and also of experimental tests held at Berlin under the auspices of the German government. The tests were conducted by a number of persons, especially Professor Pfungst, of whom we shall say more presently, and Police Lieutenant Konrad Most, who is one of the most scientific men engaged in the work of training police dogs. As a result of their findings the Prussian government has forbidden the use of police dogs in the criminal service.

A detailed account of the experiments is given in Most's book on the training of the dog for service with the police and the army and other organizations. Most's work is not yet sufficiently known

in America. For example, the *American Law Review* in 1920 printed an excellent article by J. C. McWhorter, entitled "The bloodhound as a witness," the purpose of which was to warn against the danger of convicting innocent persons, if we rely upon dogs to establish the identity of the persons in a case. Yet even the writer of this article apparently had not heard of Herr Most's work. If he had known of it, he would surely have quoted it, for it completely discredits the dog as a witness.

The fundamental claim put forth by those who advocate the use of the dog as a detective, the claim which was tested in the Berlin trials, is to the following effect: That the dog, if he be taken to the place where a crime was committed, or if he be presented with objects touched by the criminal, can, from the place or from the objects, "get" the scent of the individual who committed the crime; that he can remember this "given" scent or odor, and recognize it if he comes upon it at a future time; that he can pick up a trail having the given odor and can follow this trail infallibly, even if it is crossed by many other and fresher trails; that if the criminal mingles in a crowd, the dog can single him out by his odor and indicate him by baying at him or jumping on him.

The Berlin experiments, of which we shall now give a brief account, have demonstrated that, in regard to every item in this claim, the dog is thoroughly unreliable. The trials were open to all comers; nor was any entrant debarred from making a second attempt, in case the first attempt proved a failure. Among the entrants were prize-winning dogs from all Germany. The weather was favorable, and every precaution was taken to make the tests fair and accurate. The trials were concerned chiefly with four problems, which we shall mention in their order.

The first problem was to work out a fresh trail in proximity to other fresh trails. The tests on this problem confirmed the conclusions drawn by Herr Most from his long experience with police dogs, which he sums up thus: The dog can not be relied upon to follow the trail of one individual if other human trails cross this one, or even come near it. He switches easily from one trail to another, and often does this without hesitation, so that the trainer has no means of knowing that the switch has been made. If the alien trails are older than the desired trail, they generally do not lead the dog off; but if they are as fresh as the desired trail the dog is very liable to change to them. The angles made by the trails are important, because the dog has a tendency to continue running in one direction. An alien trail crossing at right angles is least likely to be taken up. If the desired trail bends at a sharp angle, and at or near the bend an alien trail happens to run in continuance

of the original direction, the dog almost always follows this alien trail. The same thing occurs if the desired trail traverses an unfavorable spot (for example, a much frequented street) and the dog, after crossing this unfavorable spot, happens upon a fresh alien trail.

The second problem was to work out a single trail when it was several hours old. The experimenters saw to it that the ground was absolutely free from alien trails. Twenty tests were made, upon eight different trails, the age of which was from five and a half to six and a quarter hours. The dogs failed in every test. The results indicate that a human trail ceases to be detectable when it is several hours old. A police dog can track a man most easily and surely if he is put upon the scent within a half hour from the time the man laid the trail.

The third problem was to single out an object, after being given the scent of its owner. Ten objects, belonging to as many persons, known as the test persons, were laid in a row on the greensward, each being laid down by its owner without being touched by any other human being. One of the dogs, named Flott, was brought in and allowed to "get the scent" from test person No. 3, this man holding both his hands around Flott's nose for 20 seconds. Flott was then told to fetch the object belonging to this individual. Obediently, he went to the row of objects and, after sniffing about for some time, brought No. 8, which was of course wrong, for he should have brought No. 3. In all, 17 trials of this problem were made. The number of objects used in a trial was never more than ten, and was often less. Nevertheless, in the 17 trials there were only two in which the dog fetched the right object. This is almost exactly the number of correct responses to be expected if the results were determined by pure chance. The outcome demonstrates that a dog, having been given the scent of a certain man by being allowed to smell his hands, is not able to single out from a number of objects the one that belongs to this man.

The fourth problem was the converse of the third; it was to single out a person, after getting his scent from an object belonging to him. Ten persons laid their gloves on the ground, then went to a distance and stood in a row, facing away from the spot where the gloves lay, and with an interval of three paces between each man and his neighbor. A dog was given the scent from one of the pairs of gloves, and commanded to single out their owner. In this case it was important that the test persons themselves should not know which pair of gloves had been smelled by the dog. Because, if one person had known that he was the "guilty" party, he inevitably would have expressed his thoughts in slight movements, different

from the movements of the other test persons, and this difference probably would have called the dog's attention to him. On the problem thus arranged, one dog was given four trials, without success. The number of trials in the present case was small, but the result confirms the conclusion derived from other evidence, which is that a dog, having been "given" the scent of a criminal from an object belonging to him, is not thereby enabled to single out this criminal from among other persons.

The trials which we have described were held in the year 1914. A similar series of trials was held a year earlier, with equally negative results.

Of the dogs tested in 1914, 11 were "German police" dogs (Schäferhunde), two were Airedales and two Dobermannpinscher. In the United States there is a popular notion that the bloodhound has a keener nose than any other breed. But this is a mistake, and if bloodhounds had been used in the Berlin trials the results would not have been essentially different.

In the beginning of this article we stated the fundamental claim that has long been made on behalf of the dog detective. We have now shown that the dog is unreliable in regard to every item in that statement. But that claim was extremely moderate as compared with the assertions made by some writers on the subject. A convenient summary of the affirmations formerly made by those who advocated the use of dogs as detectives can be found in the *Journal of Criminal Law* for 1912. This summary, which bears the earmarks of having been translated from some older German document, includes—in all seriousness—such assertions as the following:

> Small objects which have been left by criminals are best preserved in wide-necked bottles made of glass and sealed with glass tops; in case of necessity they may be kept in carefully washed preserve jars. As the human scent is preserved for weeks or months in such receptacles the dog can discover an accused person from among many others by taking the scent from the objects preserved in this way, even after a long lapse of time.

The meticulous care bestowed upon these bottles adds a touch of humor to the problem. The passage quoted, together with other passages in the same article, is an illustration of the fact that the belief in the dog detective developed not only into a tradition but almost into a superstition. This is an interesting chapter in human history, which will be further illustrated presently.

The conclusion to be drawn from all the facts which we have reviewed is that the dog should not be used as a witness. But a police dog is extremely useful in the performance of many other services. Herr Most says that in the work of tracking criminals a dog can be used in two ways: First, when a criminal is detected in the act, but escapes, a dog can be set on his trail at once, to follow

him by sight or sound or scent or all three combined; secondly, in cases in which the crime is not discovered until some time after the criminal has left the scene, the dog can still be used, but only as an auxiliary in the search. He may be able to work out a trail, or part of a trail, and thus assist the police in finding the evidence. The dog's behavior should not in itself be used as evidence.

The police dog is still trained to find lost articles. For in order to do this he does not need to distinguish the scent of one individual from that of another. If, for example, a purse full of money has been lost on a certain street, a policeman sends a dog back along that street, saying to him, "Verloren, verloren." In response to this word, the dog seeks and brings to the policeman any article whatever on which he detects the odor of a human being.

The dog is trained to find concealed persons in a house raided by the police. He is trained also to search a battlefield for wounded men, and to search a policeman's beat for persons who have fallen down in a faint or in a state of drunkenness or illness. In none of these tasks does he need to distinguish between individuals. In the training for the last two, he is simply taught to seek out any human being who is lying down.

We have shown that the dog is unreliable in tracking and identifying the individual criminal. Attention should be called to the fact that we have not discussed the dog's tracking power in general, and that this is a very much larger topic. Many more experiments are needed. One problem which needs investigation is this: It is doubtful whether any trainer has actually taught his dog to distinguish properly between two different commands, one of which, used in the search for wounded men, means that the dog is to seek any individual whatever, whereas the other command, used in the criminal service, means that the dog must adhere to the trail of a single individual. There are some experiments, notably those of Romanes upon his setter bitch, described in *Nature* in 1887, which indicate that a dog is comparatively reliable in following the trail of his (or her) own master. When seeking the master, the dog unquestionably does aim to adhere to his individual trail. Yet even Romanes found, in some of his tests, that his faithful setter bitch passed directly from his trail to that of a man who was a stranger to her, giving no sign that she was aware of the change. Modern experiments, with the refinements of present-day psychology, to test the ability of a dog to track his own master have not yet been tried. Nor have we any scientific data on the proficiency of the dog in tracking animals other than the human being. These are great fields of interest still waiting for investigation.

II

The puzzling fact remains that there are on record many actual cases in which the dogs that were used as detectives apparently did track the criminal and single him out from among other persons. How shall we explain these cases, which seem, on the surface at least, to contradict all that we have said? To begin with, we must admit the regrettable fact that on many occasions the acceptance of the dog's behavior as evidence has led to the conviction of innocent persons, especially in our own country, where dogs have been much used for tracking negroes. In the excitement of the chase, the white mob has not been particular as to the accuracy of their "bloodhounds" in tracking a single individual; they have accepted the result uncritically whenever their hounds "treed a nigger."

But there have been many cases, especially in Europe, in which the person tracked by the police dogs has confessed to the crime. And not only has it been proved that the dogs were right, but it has appeared that they possessed somehow a most astonishing, indeed an almost uncanny power of discovering the guilty person. The stories of these cases read like a romance—but the true explanation of them also reads like a romance. This explanation will become clearest if I preface it with an account of a certain horse who, like the dogs in question, exhibited powers which seemed at first almost unbelievable.

In the year 1904, and from then until the war broke out, all Germany was stirred to excitement over the accomplishments of certain horses, of whom the first and most famous was Clever Hans. This horse's owner, Herr von Osten, an old teacher of mathematics and a passionate lover of horses, conceiving the idea that a horse could be taught mathematics, had concentrated his efforts for years upon Hans, in an attempt to give him a mathematical education. His patience and perseverance were richly rewarded. Hans could at length answer almost any question in regard to figures and fractions, adding, subtracting, multiplying and dividing, even extracting square roots and cube roots. Such ability in a horse is contrary to all that is known regarding animal psychology. Hence, the case of Clever Hans was taken up with avidity by psychologists, especially by Professor Pfungst, the same who later superintended the experiments upon the police dogs.

Professor Pfungst found that Hans, when a problem in arithmetic was presented to him, gave the answer by pawing the correct number of times with his forefoot. And he gave correct answers to problems propounded to him by strangers, even when his owner was not present. This proved that Herr von Osten was honest; he had not trained his horse to answer by means of a code of secret

signals, such as is commonly used by professionals who train horses for money-making performances. Professor Pfungst then became convinced that every one who asked the horse a question revealed the answer by making slight involuntary movements, one sort of movement at the moment when the horse should begin pawing, and another sort of movement when it was time for him to cease; and that the horse was keen enough to observe these movements of the person in front of him and to regulate his pawing accordingly. This explanation proved to be the correct one. Hans knew nothing of mathematics, but he perceived with remarkable accuracy when it was time for him to stop pawing in order to win a prize of carrots or apples. Yet the involuntary movements made by Herr von Osten and the other questioners were so slight that Professor Pfungst was for a long time unable to detect them, no matter how closely he watched each questioner during a performance. And it was only after prolonged and elaborate research by psychological methods that he was able to give any adequate account of these involuntary expressions, to which he gave the name "minimal movements." These minimal movements play an important rôle in human psychology in the phenomena of suggestion and hypnotism, in the answering of questions by the ouija board, and in so-called telepathy, thought-transference or mind-reading, which is really muscle-reading. Professor Pfungst says: "Every horse that is good for anything is a muscle-reader; he reads the mind of his driver through the pressure on the bit—though not a word of command is uttered."

Hans was able not only by pawing to answer numerical questions, but also by other reactions to answer questions of various sorts. The following performance of his is so similar to the work of a dog detective that it can throw a great deal of light upon the latter. When confronted with a row of objects, Hans could select any one that was asked for, seizing it with his teeth and bringing it to the questioner. For example, when five cloths of different colors were laid on the ground, and Hans was told to fetch the red one, he executed this order correctly. Experiment showed that he had no knowledge whatever of the names of colors. His method of solving the problem was as follows: He walked along the row of cloths, beginning at one end, and making at least a slight movement of his head toward each cloth as he came to it. If the first cloth was not the correct one, he perceived in the movements of his master an expression of disapproval, or he heard an impatient tone in his master's voice. His tendency to reach toward the first cloth was thereby inhibited, so he passed on to the second. Thus he continued until he came to the correct cloth,

whereupon, his action being no longer inhibited by signs of disapproval, he seized this cloth with his teeth and brought it to his master.

Similarly, when a police dog is told to single out from a row of objects the one that has a certain odor, in some cases at least he is not guided by odor at all, but is governed by the expressions of approval and of disapproval on the part of his master; and by this *rapport* with his master he is caused to pass by all the objects in the row except one, and to fetch that one. There are some minor differences between the horse and the dog. For example, the horse, having his eyes on the sides of his head, can keep his master in view almost all the time, even when walking away from him. The dog is at a disadvantage in this respect. Other possible differences are not fully known, for the experiments upon muscle-reading in the dog were not carried out with the great elaboration of detail which characterized the experiments upon the horse. But the fundamental fact of dependence upon muscle-reading, which Professor Pfungst found true of the horse, he and Herr Most have found true also of the dog.

There are two sources of suggestion which have enabled the police dog in many cases to track a criminal to his hiding-place, and to single him out from among other persons: the first is the dog's master, the police officer; the second is the criminal himself.

The dog is always *en rapport* with his master and sensitive to the least hint or sign from him. This is especially true of the police dog, who has undergone a prolonged and severe course of training designed to render him absolutely submissive and obedient. In the practical work of tracking criminals, a policeman goes with the dog and generally holds him in leash. The policeman of course has a store of knowledge of criminals and their haunts, and very often when he starts out with the dog on a given case he has already made a shrewd guess as to the identity and the hiding-place of the person who committed the crime. When he has thus in his mind a certain theory on the case, it is impossible for him to inhibit the involuntary expression of his mind in his muscles. He can not help guiding the dog, no matter how honestly desirous he may be of letting the dog work out the trail unaided. Consequently, if the policeman strongly believes, for example, that the criminal is hiding in a certain house, the dog whom he is holding in leash will be almost sure to go into that house, because he will receive guidance in that direction from "minimal" jerks on the leash, or from the tones of his master's voice, or from a change in his master's steps or his attitude of body, the gestures made by his hands, or a change in the expression of his face, or from all these combined. If, on

the contrary, the dog's master remains in complete ignorance of the presumptive identity of the criminal and the location of his dwelling and all such details, then, as Herr Most says, the dog is unable to perform any of those miraculous pieces of detective work for which he has become famous. In experimental tests, from which we wish to determine exactly what the dog is able to do, every precaution should be taken to prevent him from getting the answer to his problem from the human beings present; indeed, the most conclusive tests of the dog's powers are made when no human beings are present at all.

We have said that the other source of suggestions that aid the dog in singling out the guilty person is the guilty person himself. This fact seems to have been especially prominent in the history of the so-called bloodhounds in our own country. When hounds were first used to track runaway slaves, the planters promulgated false stories as to the infallibility of these dogs in following a trail and their savageness in attacking the man whom they had pursued. These stories were believed by every one, and they were accepted as gospel truth by the poor fugitives, whose credulity was engendered in ignorance and intensified by fear. A fugitive who had disguised himself so cleverly that he could mingle in a crowd of men with a comfortable feeling that no human detective could recognize him, nevertheless trembled with awe upon the approach of a bloodhound, because he regarded this beast with an almost superstitious dread, and was firmly convinced that, do what he might to escape, the hound would come to him sooner or later, pounce upon him and reveal his identity to his human pursuers; and then, if the men did not quickly apprehend him, the dog itself would tear him to pieces. The fugitive's own fear thus betrayed him and led to his recapture. For the dog has apparently a natural tendency to perceive the signs of fear and to be excited by them; consequently, he barks at a person who shows fear.

But as time went on, negroes and criminals and escaped convicts gradually learned that bloodhounds are by no means infallible. Ceasing to show fear, they thereby ceased to betray their identity to the dog detective. And even if in some cases they were apparently singled out by the hound, this was no longer sufficient, as it had formerly been, to induce them to make a confession. The history of police dogs in Europe has been, in these respects, a repetition of the history of the bloodhound in the United States. Dogs were first used as part of a modern police force in 1899 in the city of Ghent, Belgium. The dogs immediately did splendid work in subduing the rough element of the city. Their praises were sung in the newspapers and magazines of the whole world. Their use

spread quickly to other countries in Europe and to Asia and America. They were a new weapon of attack upon the criminal, for which he was not prepared, and they had him thoroughly scared. The tracking of a criminal by a dog was in a great many cases followed by his confession. But now, after twenty years' experience, the criminals have learned that the dog is liable to error; consequently, the dog's witnessing against them does not force them to confess.

Thus it would appear that the extraordinary feats performed by dog detectives are matters of past history—partly true and partly legendary. The psychologists at Berlin have shown the absurdity of the exaggerated accounts of the dog's power of scent. In exposing this error, however, they have opened to us a new and fascinating field of canine psychology: they have given us a glimpse into the dog's powers as a mind-reader. But in this field, again, one must beware of the danger of exaggeration. The dog does not understand his master's purposes. He does not ask why in one case he is to seek only persons who are lying down, whereas in another case he is permitted to pursue a man who is running at full speed. He does not know that one man is wounded or sick, and that another is a criminal. The aim of the obedient dog is simply to behave in such a way as to win the approval and avoid the disapproval of his master. But he does this so keenly that he mirrors the thoughts of his master as faithfully as the hypnotized subject mirrors the thoughts of the hypnotist.

PLANT LIFE OF BRITISH INDIA

By Professor L. A. KENOYER

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No region on earth of equal size presents the climatic extremes to be found in British India. Here are all gradations of rainfall, from over 460 inches per year at Cherrapunji, Assam, to less than 3 inches in parts of Sind. Here are all temperatures, from a maximum of 128° F at Jacobabad to a minimum far below zero at the tops of the highest Himalayas. Hence, as we should naturally expect, the diversity of the vegetation and the number of species is very great. In Hooker's "Flora of British India" are described 17,000 species of flowering plants, while in Gray's "Manual of the Central and Northeastern United States and Canada" are less than 4,000. Yet the area covered by Hooker is hardly twice that covered by Gray.

Perhaps the most striking thing about the flora of India is its lack of peculiarity. An astonishingly small proportion of the genera and none of the families are endemic, that is, restricted to India. The great bulk of the species or their immediate ancestors have come in from adjacent lands or from neighboring lands overseas. Sir Joseph Dalton Hooker, than whom there has been no greater authority on Indian botany, says that in a large sense there is no Indian flora proper. The Malayan element is the dominant one, but intermingled with it are large numbers of plants from the Western Asiatic, European, Arabo-African, Siberian and Chinese floras besides a small but increasing number of American plants. The Chinese and Malayan forms abound in the east, the European, Western Asiatic and African in the west, while the European and Siberian are most plentiful in the Himalayas.

In India are represented all the leading types of the world's vegetation with the exception of the prairie. High temperatures, such as prevail over much of the area, are said to be unsuited to herbaceous grasses. Furthermore, a markedly periodic rainfall seems to be better adapted for trees, because they can draw upon the subsoil reserves of water during the dry season. There are usually grasses in abundance mixed in with the forest trees or with the desert scrub, but there are no large areas of pure grassland. Practically the entire peninsula is so completely under the sway of the monsoon conditions—the periodic recurrence of rainy and dry seasons—that it supports a vegetation decidedly periodic in its be-

FALLS OF THE NIRBUDDA RIVER, CENTRAL INDIA, WITH MONSOON FOREST IN THE BACKGROUND

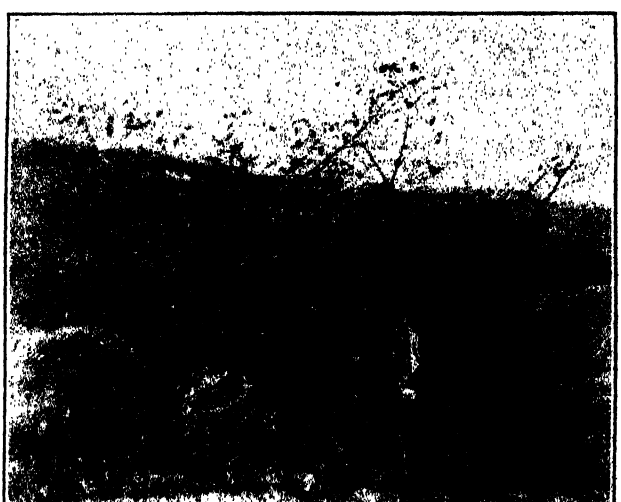
havior. In most of India this is the monsoon forest of the plant geographer. In the west it grades into the thorn forest, the scrub and the desert, with gradually decreasing amounts of rainfall. In the portions with greatest rainfall, as the southwestern coast with its bordering mountains and the general region of the Ganges delta, there are so many evergreens that the plant formation approaches the tropical rain forest in character. It is doubtful whether even here we can consider it a typical rain forest, for it is subject to a rainfall of decidedly periodic distribution.

In the northeastern United States the leading five families of plants are Compositae, Cyperaceae, Gramineae, Rosaceae and Leguminosae, while in India they are Orchidaceae, Leguminosae, Gramineae, Rubiaceae and Euphorbiaceae. The Compositae is seventh and the Cyperaceae eighth in numerical importance in India. The orchids, which take the lead in India, are most numerous in the humid eastern Himalayan region.

The writer is most familiar with that portion of India which is known as the Upper Gangetic Plain, a comparatively level tract extending about 600 miles northwestward from Benares and occupying a breadth of about 200 miles between the abrupt rise of the Himalayas on one side and that of the Vindhiyan plateau on the other. This is a vast expanse of river alluvium, thousands of feet

in thickness—the débris of the Himalayas and of the much older plateau of peninsular India. It is almost level except where the rivers and their tributaries have cut deep gullies into the easily eroded silt. Supporting an agricultural population of 400 to 700 per square mile, it is practically all in cultivation except where the soil is too alkaline or too much eroded. The cutting of timber and the intense grazing of waste areas together with cultivation have reduced the forest which formerly occupied the area to a few straggling trees of types capable of undergoing the most strenuous treatment. Prominent among these are certain Leguminosae, such as *Dalbergia sissoo, Butea frondosa, Acacia arabica* and *Albizzia lebbek.* Butea, which is sometimes called the "flame of the forest," forms extensive groves on level tracts of land. In March the leafless tree is an impressive sight with its mass of shiny orange-red flowers. The pod hangs with a seed at the distal end, the remainder being flattened into a wing six to eight inches long for the dispersal of the seeds. The large leaflets are sewed together to make baskets and plates for household use. Acacia is the source of gum arabic and many other useful products. It is a native of northwest India, Arabia and Egypt, but has escaped everywhere on the Indian plains. The "Neem tree" (*Melia azadirachta*) is a graceful tree which springs up spontaneously almost everywhere.

One can scarcely conceive the extent to which vegetation has been modified. India has a very dense human population, 320,000,000, and supports nearly half as many cattle, or, if we count domestic animals of all sorts, nearly as many as the human population. In a large portion of the Gangetic plain each acre must sup-



Zizyphus ocnoplia, A THORNY PIONEER SHRUB OF GRAZED AREAS

port one person and one domestic animal. As cattle are considered sacred animals, those of no economic worth are allowed to run at large, grazing where they may. This intensive pasturage has a profound effect upon vegetation. Wherever animals graze, the plants that persist belong to three categories—those that are protected from animals by spines, those that are not eaten because of a bitter or unpalatable flavor and those that have buds next the ground where they can not easily be reached by animals. The spines of the great majority of spiny shrubs and trees, as species of Acacia, Capparis and Zizyphus, are modified stipules. In Zizyphus one spine points forward and the other curves backward, so the animal is caught in both the advance and the retreat. To the class with protected buds belong the grasses, of which there are many species, and a number of tufted mat-forming deep-rooted perennial herbs. Government experiments on afforestation show that when animals are kept off a tract of land a good growth of trees takes place in a few years.

A given area is subject to far greater extremes of humidity than is often experienced in temperate zone habitats. 90 per cent. of the rain falls in three months, from the middle of June to the middle of September. During the rainy period a given area may be wet meadow, or, if the soil becomes waterlogged and drainage is inadequate, it may, towards the close of the period, become a swamp or a lake. After the rains cease it gradually dries, and for six months or more is capable of supporting only a xerophytic flora. A lake in temperate America has around its margin vegetation zones made up of plants suited to different depths of water or to different amounts of soil moisture. The water level in most cases changes somewhat during the season but not enough to cause any serious disturbance in the established zones. In India the change of level is so rapid and thoroughgoing that we find, as a rule, no permanent zonation. There may be a temporary zonation—a border of small annuals growing near the water's edge and receding with the drying of the pond. A plant frequently present in such situations is *Glossostigma spathulatum*, a minute member of the Scrophulariaceae, which probably grows from seed to maturity in three or four weeks, hence is able to complete its life cycle before the substratum becomes too dry.

Common on the plains and over large portions of India are flourishing groves of planted trees. Perhaps the most important of these is the mango (*Mangifera indica*), a fruit native to and highly prized throughout India.

In the peninsula to the south of the Gangetic plain there is much hilly and rocky land. The population is less dense, hence

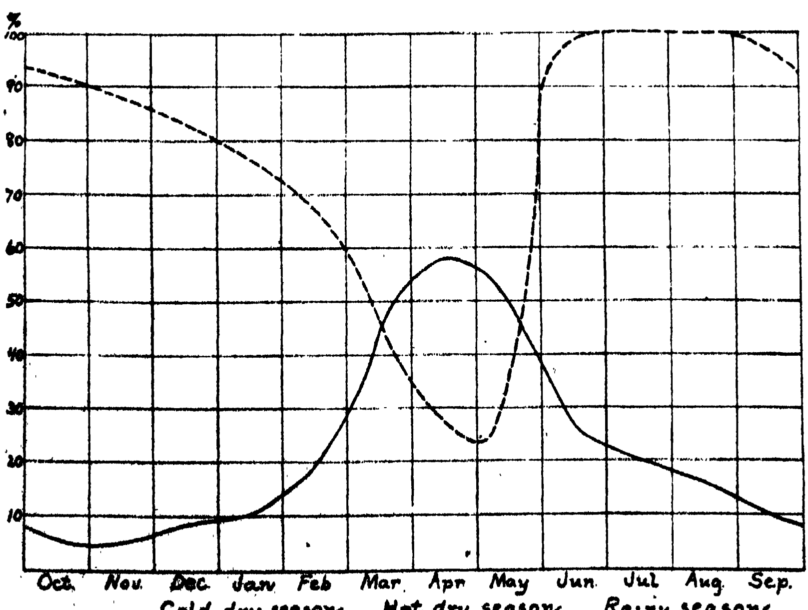
Sterculia urens IN LEAFLESS CONDITION, WHICH PERSISTS FOR MONTHS. FRUIT RIPE. [CHITRAKOT, DECEMBER 1920.]

trees have a fairly good opportunity to become established. The eternal quest for fuel prevents them from becoming very old, but in some localities are government reserves where the trees are protected from cutting long enough so we may form a conception of the aspect of the monsoon forest. In one of these forests in April, when the thermometer reaches a daily maximum of about 110° F, the trees are so bare that it is with difficulty that one finds shade from the broiling sun. Such few evergreen trees and shrubs as exist are found in the ravines where the water supply continues for a longer period.

The trees of the tropical monsoon forest are not so uniform in their behavior as are those of the temperate winter-deciduous forest. In the latter, the coming of frost seems to determine to a large extent the time of the shedding of leaves, while in the former there is no definite time for the leaves to fall. Some species, as *Erythrina suberosa, Bombax malabaricum* and *Sterculia urens* shed their leaves about a month after the close of the monsoon rains and remain naked for seven or eight months. Others, such as *Bassia latifolia* and *Melia azadirachta*, keep their old leaves until almost time for the new ones to appear, hence are leafless for less than a month. In fact, some of the trees are not at any time entirely leafless. For a number of years I have watched the leaf-fall of a tree of *Artocarpus lakoocha.* The shedding begins at the tip of the tree and passes in a wave towards its base, the whole process occupying

about a week. Before the leaves fall from the lowermost limbs the new crop on the topmost limbs is well advanced. The time for the changing of foliage in trees of this type may be, in different species, anywhere from January to April. The rainy season commences late in June or early in July, but few, if any, of the trees await its coming for the development of their new leaves. On the contrary, many of them will go through a long period of severely dry weather clothed in the tender new foliage. The stimulus that impels leafing is not very well understood, but the increasing temperature of spring would seem to have some bearing on it. There appears, also, to be a relation between reproductive activities and the appearance and disappearance of foliage. A young tree, or one which for some other reason does not blossom, retains its leaves after a blossoming tree of the same species has dropped its foliage. *Odina wodier* is a diecious tree of the Anacardiaceae. Shortly after the flowers drop the male tree begins to put forth its leaves, while the female tree does not open its leaf buds until the crop of fruits is mature.

A single species, even, in the monsoon forest is quite erratic in its behavior. We expect in the temperate forest to find the white oaks or the shellbark hickories doing practically the same thing at one time. But, for example, if we go in late April into a persimmon (*Diospyros tomentosa*) grove in central India we should find trees



RELATION BETWEEN LEAFINESS AND FLOWERING IN INDIAN MONSOON FOREST
The broken line represents percentage of leafiness, the solid line percentage of trees in flower.

with last season's foliage complete, shedding trees, bare trees and trees putting forth new leaves. We should find flower buds, flowers and fruits in different stages of development. One has difficulty convincing himself that the trees all belong to the same species.

There is a reciprocal relation between leafing and flowering in the monsoon forest. In the figure the broken line shows the average percentage of leafiness of 100 representative species of trees of the monsoon forest as determined by the writer in several different localities at different times of the year. The solid line shows the percentage of the same 100 species found in blossom month by month, the time of blossoming given in Brandis' "Indian Trees" being used. It will be seen that the highest point of the blossoming curve almost coincides with the lowest point of the leafiness curve, and vice versa. The development of the blossom buds may draw moisture from and hasten the fall of the leaves. In the distribution of pollen and the later distribution of fruits, there is no doubt an advantage in having the tree free from leaves.

The monsoon deciduous trees have for the most part scaly buds, but the scales are less conspicuous than in most of our winter deciduous trees. In the forests of the plains there is a scarcity of herbs with fleshy perennating organs, as bulbs and tubers.

Perhaps only one tree of the central Indian forest escapes com-

THE "MAHUA" (*Bassia latifolia*), A MONSOON DECIDUOUS TREE OF THE PLAINS, SHOWING HOW THE LEAVES ARE SHED FROM THE TOP DOWNWARD

Odina wodier, A MONSOON DECIDUOUS TREE, WITH FRUITS. HOT DRY SEASON

pletely the woodsman's axe. This is the "mahua" (*Bassia latifolia*). Its spherical fleshy white flowers, rich in sugar, fall to the ground in the early morning and are gathered to be eaten fresh or dried or to be made into "sharab," one of the favorite distilled liquors of India. Its fruit is edible, and its seed yields an oil valuable in cooking and for medicine.

The teak (*Tectona grandis*) is an exceedingly valuable forest tree in Burma and only somewhat less so in central India. Its wood is highly prized for cabinet work. It is a typical monsoon tree, its large simple elliptic leaves, which sometimes attain a length of two feet, lasting only a little over half a year. It is of such widespread occurrence that it might be considered the dominant tree of the climax monsoon forest.

The genus Ficus is a noteworthy one among Indian trees. Its best-known representative is the banyan (*F. benghalensis*), a single tree of which, by reason of its widespread branches and the prop roots which sustain them, may resemble a small grove. A tree in the Calcutta Botanical Gardens has about 500 of these prop-roots and covers two acres of ground. *F. religiosa*, the "pipal" or "bo" tree, was regarded sacred by the Buddhists, who occupied India twenty centuries ago, and is still so considered by the Hindus. Many a devotee places before the tree a small lighted lamp or an offering of food or flowers to appease the spirit which is supposed

to inhabit the tree. The leaf has a long attenuated tip designated by Kerner as a drip-tip and said to be advantageous in draining surplus water from the leaf. But any such advantage is doubtful, since the leaf hangs downward in such a manner that water could not in any case remain upon it, and since the tree is native to a portion of India where the rainfall is not excessive. Of considerable interest, also, are the strangling figs, as *Ficus rumphii*, which begin growing in the crotch of another tree, then surround the sustaining tree with a network of roots extending downward till they strike the soil. On the death of the sustaining tree this skeleton root system may be strong enough to support the Ficus.

Bamboos, particularly *Dendrocalamus strictus*, are abundant in many parts of the forest. This is not a particularly large form, but it forms conspicuous clumps in places. In famine years its leaves are of some value as a cattle fodder, and the grain, which is spasmodically produced, is a good substitute for wheat.

Mention should be made of the palms, two of which, the wild date (*Phoenix sylvestris*) and the palmyra (*Borassus flabellifer*), are common, wild or planted, over a great portion of India. The latter is used as a source of fans and for the making of a popular alcoholic liquor. Both have been utilized in the manufacture of sugar. The cocoaunt palm is restricted to the regions near the coast, especially southward. Kipling's words, "we hold dominion over palm and pine," may be exemplified within a very small com-

THE BANYAN (*Ficus benghalensis*), SHOWING FOUR LARGE PROP-ROOTS WHICH HELP TO SUSTAIN THE BRANCHES

A STRANGLING FIG (*Ficus rumphii*) WHICH HAS GERMINATED IN THE CROTCH OF A LIMB AND SENT ITS ROOTS DOWN TO THE GROUND

pass in certain parts of the outer Himalayas, for the uppermost palms (Phoenix) just reach the lowermost pines (*Pinus longifolia*).

The forest type just described covers the greater part of peninsular India and is doubtless the largest monsoon forest in the world. About Madras, where most of the rain comes with the northeast monsoon during the winter months, the aspect of the vegetation seems to change. Here is probably a greater percentage of evergreens with broad thickish leaves, such as we often find in areas with the rainfall limited, but distributed through the year. Here along the sandy shore are groves of beefwood (*Casuarina equisetaefolia*), a tree which at first glance suggests a pine, but which on

close examination is seen to have fluted and jointed branchlets, with scale-like leaves, much resembling those of Equisetum. It is used mainly for fuel. In Bengal and Assam, in Burma and along the Travancore coast, the increased rainfall increases the number of evergreens of the rain forest type. The dense impenetrable jungles of the type familiarized by Kipling are found mainly in the hilly regions of the southern tip of the peninsula, although a jungle is in reality any uncultivated piece of ground, whether growing in trees, shrubs or grasses.

The present Indian flora contains many introduced plants, American ones being especially prominent. It is said that about the year 1800 an effort was made to introduce the cochineal insect from Mexico into India. A species of prickly pear (*Opuntia elatior*) was taken over to serve as its food plant. The insects did not thrive, but the cactus is now to be found growing all over the drier parts of India, planted in fencerows or growing spontaneously. In the famine year of 1918–19 thousands of cattle in the Bombay Presidency were saved by its use, the cactus being first singed with a gasoline torch to destroy the prickles, then chopped and mixed with concentrated feedstuffs. Species of agave from tropical America have also been widely planted. American forms are numerous among the ruderals and weeds. Among other widespread ones are the Mexican poppy (*Argemone mexicana*), the spiny amaranth (*Amaranthus spinosus*) and *Tridax procumbens*, one of the Compositae which distributes its seeds, as does the dande-

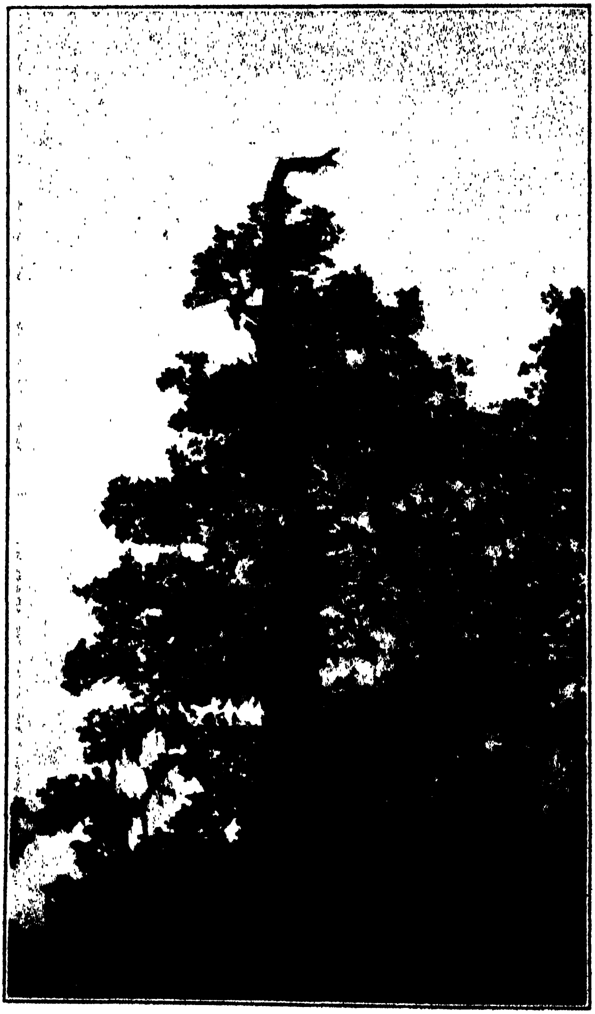
JUNGLE OF *Ficus glomerata*, TERMINALIA ARJUNA, AND THE LIANA *Phyllanthus reticulatus*, IN A VALLEY ON THE VINDHIYAN PLATEAU

lion, by a windborne pappus. *Galinsoga parviflora*, a weak-looking South American Composita which has recently found its way into many of our cities in the United States, has become widely distributed over the Himalayas in India. The upper Gangetic plain alone has no fewer than twelve American Compositae, some of them so recent that they have not been included in the manuals. There is no more fascinating story in the realm of botany than that of the occupation of new territory by plant immigrants.

The really thrilling field of operation for the botanist in India is the Himalayas. Here, in a zone of 50 to 75 miles breadth, we have condensed, as it were, the plant formations of the world from the equator to the poles. Starting from Kathgodam or from Dehra, we may pass through tropical and subtropical monsoon forest zones, a warm temperate semiarid pine forest of trees allied to our southern long-leaved pine, three distinct oak forest zones, a cold temperate deciduous forest of maples, elms, alders, buckeyes, poplars and the like, a forest of cedar, pine, spruce and cypress allied to our northeastern evergreen forest, a subalpine forest of fir and white birch, an alpine shrub zone, alpine meadows and, at last, perpetual snow.

The hills rise quite abruptly from the plain. At their foot the seepage, together with the heavy rainfall that comes from the condensation of the moisture in the landward-moving air currents at this place, give rise to a dense jungle. Here the elephant and the tiger abound, where civilization has not encroached too closely upon their haunts. Here in the tertiary geologic period were the ancestors of the present-day elephant, the fossil remains of several species having been discovered. There are really two vegetation zones at the foot of the hills. A few miles out are swampy areas occupied by grasses, rushes, cat-tails and a few scattering trees, among which *Bombax malabaricum* is conspicuous. Nearer the base of the mountains, where the débris is coarser and the drainage better, a dense forest is supported. In this zone and on the lower slopes of the hills is found the "sal" (*Shorea robusta*), one of the most useful timber trees of India. It forms almost pure stands of tall remarkably straight trees conspicuous by their black bark and dark green foliage. In the zone just above this the leading trees are several species of Bauhinia. These are leguminous trees easily recognized by the twin-leaf, two leaves having apparently grown together to form one. A number of other tree Leguminosae are here represented. In April, when the foliage is scanty, several of the trees are in bloom, making the forest gorgeous with masses of scarlet, purple, white and yellow. Woody climbers and mistletoes are abundant in this zone.

The long-leaved pine (*Pinus longifolia*) forms almost pure for-



OAK WITH HANGING "MOSS",
Quercus semecarpifolia, with the lichen Usnea on its branches. [Nag Tiba, 9,500 ft. June 1917.]

ests along the crests of ridges and in other dry exposed situations. Its foliage is very sparse during the dry season. It is useful as a source of resin and lumber.

The broadest zone of all is occupied by the silver-leaved oak (*Quercus incana*). It is conspicuous at a distance by the silvery sheen of its lower leaf surface. Above this is the holly-leaved oak (*Q. dilitata*), with its leaves smooth and shiny green on both sides, while in a still higher zone is *Q. semecarpifolia*, which has a copper-colored pubescence on the lower surface of the leaf. These oaks

are evergreen with the exception of the last, which may be bare for a short period. Growing in an altitude in which winters are not very severe nor summers very dry they have adopted a leaf habit which enables them to take advantage of any favorable periods for foodmaking throughout the year. The Himalayan oaks all belong to the biennial-fruited division, and like most representatives of this division they are of little value for lumber. Yet no tree is more sought after by the hill resident. Near the village the trees are grubbed out so that the land may be tilled; just beyond this they have been cut for building timbers, for fuel or for making charcoal; still farther out the branches have been mercilessly lopped off for use in thatching, as cattle fodder during the cold and the dry seasons, as fertilizer for the fields or perhaps for the tanning of leather. It is due to its wonderful power of recovery that the oak remains so abundant.

In the ravines of the oak forest are several evergreen members of the Laurel family, the box, the holly and a beautiful flowering dogwood (*Cornus capitata*) similar to our *Cornus florida.* Mixed with the oak are two trees of the Heath family, *Rhododendron arboreum,* which is resplendent in the spring with red bell-shaped flowers three inches long, and *Pieris ovalifolia,* with waxy-white drooping urn-shaped flowers. While the greater proportion of the trees of this zone belong, as does the oak, to the broad-leaved sclerophyll group, there is quite a sprinkling of winter-deciduous forms, among which are a Prunus, a Pyrus and a Crataegus. At least four species of barberry are found here, and on some of them may be seen the aecial stage of the wheat rust.

Our consideration of the hill vegetation should include some remarks concerning especially modified forms. Lianas are abundant, particularly in the lower zones. The largest is *Bauhinia vahlii,* known as the elephant creeper. As much as one fourth of an acre of forest has been covered by a single plant of this huge climber. With its large elephant-ear leaves and its velvety bean pods 18 inches long, it gives a semblance of reality to the story of Jack's beanstalk. There are a number of climbing aroids, besides species of Ficus, Vitis and other plants with a similar habit. The hemiparasitic mistletoes abound. Loranthus and Viscum are the leading genera, but on *Pinus excelsa* may be found the tiny *Arceuthobium minutissimum,* said to be the smallest dicotyledon on earth. There are several hemiepiphytes, like the strangling figs, which start as epiphytes and later make connections with the ground. There is a host of true epiphytes, including lichens, mosses, ferns and flowering plants. At the height of the rainy season the branches of the oak, in particular, are almost masked with the profusion of

HYGROPHYTIC VEGETATION NEAR A WATERFALL AT 5,000 FEET IN THE HIMALAYAS

these epiphytes. In the higher oak forests is an abundance of the lichen Usnea hanging in long streamers from the branches of trees.

The undergrowth of the hill forests resembles in large degree that which we find in our temperate forests, with the addition of certain tropical families, as the Begoniaceae, Gesneriaceae and Zingiberaceae. In the spring are found representatives of the temperate zone families, such as Ranunculaceae, Cruciferae, Caryophyllaceae, Violaceae and Crassulaceae, while after the beginning of the rainy season in June the representatives of the tropical families are at their best. Then come goldenrods, asters and Senecios, similar to those found in the temperate forest in autumn.

Beyond the range of the oaks we encounter a sprinkling of alders, elms, maples and other winter deciduous trees, mainly in the valleys. Above this the higher coniferous forest is encountered. Its dominant tree in the western half of the range is the deodar or Himalayan cedar, a near relative to the Cedar of Lebanon. "Deodar" signifies "gateway to God," and the tree was well selected to symbolize divinity, for no tree surpasses it in beauty and symmetry. Like *Ficus religiosa* on the plains of India, *Cedrus deodara* in the hills is everywhere associated with temples and shrines. Mingled in the deodar forest, but principally around its edges, are found the blue pine (*Pinus excelsa*), the spruce (*Picea morinda*) and the Himalayan cypress (*Cupressus torulosa*).

The uppermost Himalayan forest is a mixture of *Betula alba* and *Abies webbiana*. This species of birch extends around the world in the subarctic regions, and with it may be associated species of fir. On the Himalayan mountain sides the dark fir trees stand out conspicuously against the white birch. At 10,000 feet the writer found the birch trees just coming into leaf the middle of

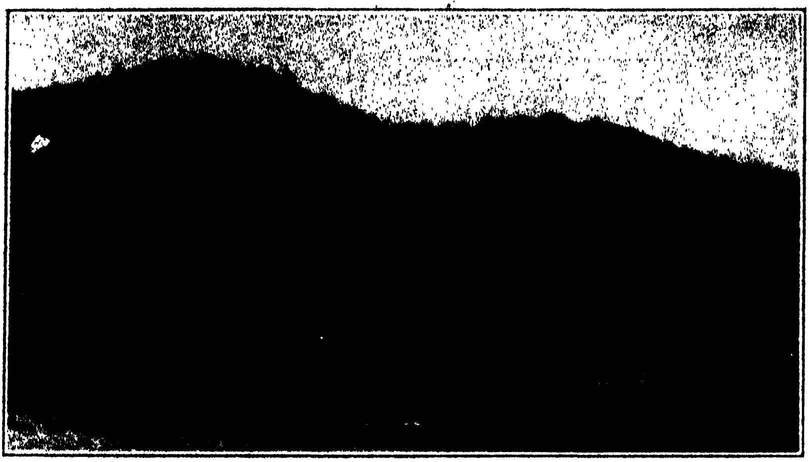
HIMALAYAN CEDARS (*Cedrus deodara*) GROWING BESIDE A PATH

BRANCH OF *Quercus incana* LADEN WITH FERNS AND OTHER EPIPHYTES. HIMALAYAS AT 7,500 FEET

June. At greater elevations the firs drop out, leaving a birch forest with a slight admixture of mountain ash and shrubby rhododendron. So great is the accumulation of snow in winter that at times the birch trees lie prostrate on the ground.

Above the forest is a shrub zone made up largely of spreading junipers (*Juniperus communis* and *J. macropoda*) and the peculiar Equisetum-like *Ephedra vulgaris*, with bush rhododendrons and other forms. An element of the depauperate Tibetan flora comes in places through the high mountain passes and occupies the Indian side of the range. Above the shrub zone is the mountain meadow with its buttercups, primroses and cinquefoils, the vegetation becoming more and more scanty as greater heights are reached. More than 30 species of flowering plants have been found at the altitude of 18,000 feet. This is ordinarily considered as about their upper limit, but the Mount Everest expedition of 1922 found the edelweiss flowering at almost 20,000 feet. Even above this tremendous height it is more than 9,000 feet or almost two vertical miles to the "top of the world," a monotony of bare rocks and snow unbroken by vegetation except, probably, a few lichens.

The flora of Nepal, a kingdom occupying about 500 miles of the length of the Himalayas in their central portion, is practically unknown, but we have some evidence that this is a sort of transition zone between the Eastern and Western Himalayan flora. The Eastern Himalayas, on account of their warmer, moister climate have a flora which is more luxuriant and more largely tropical than that just described for the Western Himalayas.



A SOUTH-FACING SLOPE AT 4,500 FEET ALTITUDE, WESTERN HIMALAYAS. IN THE VALLEYS MOSTLY *Quercus incana*, ON THE RIDGES GRASSLAND, AT THE CREST PINUS LONGIFOLIA

The following will show the parallelism between the vegetation zones encountered in travelling northward in eastern North America from the southern tip of Florida to northern Labrador, and that found in a journey from the base to the summit of the Himalayas. In the former case the crossing of these zones would involve a journey of about 3,000 miles, while in the latter 60 miles in direct line would suffice.

America	*Himalayas*
Tropical forest	Shorea-Bauhinia forest
Southern mesophytic pine forest	Pinus longifolia forest
Live oak, water oak, laurel oak, etc.	Oak zones
Beech-maple forest	Maples, alders, elms, etc.
Northern coniferous forest	Upper coniferous forest
Birch forest	Birch forest
Tundra	Alpine shrub and mountain meadow

Thus India, about half the size of the United States, is a vegetational world in itself and embraces a horde of botanical problems, the solution of which, aside from contributing to the maintenance of the vast underfed population, will cast much light on the larger problems of the world's plant distribution and plant behavior.

THE CULT AND EARLY ECONOMIC ORGANIZATION

By Professor HERBERT MAYNARD DIAMOND
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The Primitive Struggle for Existence

As a general thing we do not to-day club our aged relatives on the head with the kindly intent of settling for them once for all the problem of living. Indeed, contemporary society views such conduct with some little disfavor. However, on this continent some groups of our aboriginal predecessors not only pursued this practice but regarded it as quite the sporting thing. Life necessities compelled resort to some such expedient. The old, who could no longer engage in the chase and no longer endure the constant physical exertion demanded by a wandering life, were far too great a burden for the active to carry. Hence, as in several other parts of the globe, this primitive solution of the matter.

It would be difficult to select an illustration indicating more forcibly the differences in the character of the struggle for existence as between civilized and uncivilized men. The life problems of each differ profoundly. Men of advanced culture have thrown up barriers between themselves and the operation of natural forces. As contrasted with primitive conditions the operation of the natural processes of selection has been checked to a marked extent. He who, by cause of disease, blindness or loss of limb, would under primitive conditions have been compelled to die is now cared for tenderly, and if need be at the expense of the present-day community. While such a person is thus removed from the *struggle for existence,* he is not removed from existence. As a group we no longer really struggle to live; our struggle is to make life richer and fuller. Our advantages and knowledge make it relatively easy to maintain life, and our toil is not with that sole aim.

Among primitive men the foremost problem of life was to live. They had no such social or mental equipment as ours. They never could far remove themselves from the direct pressure of natural forces. Their means of dealing with nature were from our viewpoint crude, undeveloped and insufficient. For the most part nature eliminated the individual who could not carry on the struggle, for the social surplus was not great enough to provide for the unproductive. Such groups were never, as are we, independent

at any time of their local environment. A failure of supplies in an area could mean for them only evacuation or death. Insurance against the disaster of the morrow was scarcely certain. In our early history the experience of the first Jamestown colony indicates what may happen to civilized men when removed from contact with the outside world, and when facing an unfamiliar environment. No primitive group ever brought to bear on their life problem the mental and social outfit possessed by these colonists. The failure of this group to meet the situation in the new land points the regular facts of primitive life.

The Aleatory Element

In this struggle for life and in their efforts to realize their interests, early men were far more exposed to the play of that factor in experience which we term chance or luck than are modern men. If chance is conceived to be that in experience which can not be figured out beforehand (including those experiences whose relations to their antecedents can not be predetermined, foreseen or controlled) it may be readily understood that in a state of primitive ignorance the element of chance was incalculably great. For early man could not foresee, control, avoid or prepare for in advance any number of things which are simple problems in cause and effect to civilized men. Without an accumulation of knowledge foresight becomes limited in range; without generalization from experience the result of effort may become a matter of speculation rather than of certainty. Normally, when a modern individual puts certain forces into operation he can, within limits, foresee the results. Early man neither knew nor understood the forces. Hence, in his struggle to live early man could do little else than make effort after effort without knowing how these efforts were to turn out.

For this condition of life primitives could make no rational accounting. That it was a fact of life none could question. Their subjection to the caprice of fortune lay in a twofold set of causes. On the one hand they possessed no accumulation of the experience of preceding generations of men. There existed very little from which there might be drawn a knowledge of the efforts and of the successes and failures of those who had gone before. Many a life emergency appeared as something to be met anew. On the other hand, this very circumstance forbade any appreciable growth of science. Without an accumulated record group experience causal relationships can not be established with continued accuracy. Sufficient evidence was lacking among early men upon which to base inclusive judgments of such relationships. Again, a laggard mental development hindered an approach to scientific understanding

of relations between causes and effects. Among primitive men there existed, therefore, a range of experience which lay outside their capacity either to control or to explain. "This was the aleatory element in life, the element of risk or loss, of good or bad fortune."[1]

Such a condition of existence called for some attention. Facing a situation in which at every turn an unforeseen and incomprehensible difficulty or disaster might arise early man strove to find a means of dealing with it. Here was an ever-present and obvious feature of the game of living. Its importance was vital to his interest; yet to deal with it he had to account for it. However, he could not rationally size up the case and then rationally seek to go about meeting it. Rather, feeling a need he struck out in vague efforts to account for his difficulties and then to deal with them.

Notions of Agency

Early man, however, had at hand a ready explanation of everything which demanded explaining. Primitive men, in general, ascribe all incidents either to the agency of men or of spirits. So that, in their interpretation of this otherwise inexplicable phenomenon of chance in their lives, they traced causation to the activity of spirits which were believed to surround. The origin and basis of primitive belief in the existence of spirits is not our problem here. The fact is that such belief prevailed; and on this set of ideas there existed for early man an entirely satisfactory explanation of the phenomena of chance. In the social organization of every primitive society, for this reason, there is to be found a characteristic response to this combination of ideas.

The primitive view confused cause and agency, holding that results were largely due not to any impersonal cause (of which there was no general conception) but to an agency of some sort. The latter idea was one with which they were perfectly familiar. Agency and cause were never dissociated in their mental processes. The inexplicable and the unforeseen were attributed to the action of some sentient personality. A concept of natural law and cause never, even dimly, developed among their ideas; active and personal forces were conceived to actuate all events. Illness and death, for example, were phenomena for which the lower cultures had no rational explanation with respect to their causes. These, furthermore, were misfortunes as great as early man might conceive; as indeed with us. Primitive groups traced both in origin to spiritual agency. The Central Australians have no idea of natural death. It is always due to supernatural causes.[2] Roscoe, writing of the

[1] Sumner, W. G.: "The Folkways," 6.

[2] Spencer and Gillen: "Native Tribes of Central Australia," 467, 477.

Umganda in Africa, says: "To the mind of the Umganda there is no such thing as death from natural causes, it is always due to a spirit or to witchcraft."[3] Similarly the Teneda of French Guiana do not consider illness and death as natural and normal. "They ar always, among them, the result of an accident provoked by the intervention of a divinity or of some genii. Normally they considered they would not die even in the case of old age."[4]

In the case of misfortune of a more general character the same tendency is evinced by primitive groups; the unaccountable otherwise finds explanation by the attribution of cause to supernatural influence in the affairs of men. The Dusuns attribute "All such calamities as epidemics, failure of crops, etc., to the agency of their Gods."[5] Amongst the Siamese the anger of the "clan spirits is the fruitful cause of every disease and disaster that flesh is heir to."[6] Monier Williams declares that among the Hindus "all disease that either human or bestial flesh is heir to are personified and converted into demons, such as the demon of small pox, cholera and the various forms of typhus and jungle fever and of cattle diseases, and this idea of personifying and demonizing diseases is extended to unseasonable calamities and disasters, such as hail storms, droughts and blight, which all do duty in the devil army."[7]

The Imaginary Environment

All primitive men were convinced that they were surrounded by spirits, and that these spirits exerted an incalculable and unlimited influence upon mundane affairs. This belief and the reactions of society upon it are typically human phenomena; there is nothing akin to them elsewhere in nature. The human intellect with its capacity of forming ideas was led to interpret psychological phenomena and those of outside nature with the result that a belief in the existence of an otherworldliness was established. The very superiority of human over animal intelligence made men subject to such illusory concepts—lines of reaction which the lower animal mentalities could never have pursued. Through their reactions of this character, early men were compelled to add another plane to their physical and tangible environment. This we may term the imaginary environment—the surrounding spirits of various grades and authority.

[3] Roscoe: "The Umganda," *Jour. Anth. Inst.*, 31, 121.

[4] Delacour: "Les Teneda," *Jour. d'Ethnology et de Sociologie*, 4, 105.

[5] Evans: "Religion, superstitions, ceremonies of the Dusuns," *Jour. Anth. Inst.*, 42, 380, 381.

[6] MacGilvray: "Half Century among the Siamese," p. 203.

[7] "Brahamanism and Hinduism," 41.

Keane remarks that "all savages however degraded, if they are capable of reflecting at all, are compelled to think and reason about the dreams and visions of their sleeping hours and about the natural phenomena surrounding their daily existence. These they naturally attribute either to the shades of the dead or to invisible beings, superior perhaps, but still resembling themselves, some friendly, some hostile, and all entering into the normal condition of things."[8] His last phrase epitomizes the primitive view of things. Early man viewed the spirit world as a reality and as a fixed part of his life experience. Lippert comments in writing about this point that the strength of an idea lies not so much in its truth as in its vividness and the number of people who believe in it.[9] Both these conditions were satisfied in early society.

The Basis of the Cult

Men of every age and race strive to adapt to the conditions of life which they perceive or think they perceive to surround them. To avoid pain and obtain greater results with less effort is a common impulse of humanity. Primitive men in their attempts to adjust themselves to their environing situation were compelled to make allowance for a factor in environment which we no longer recognize—the presence of the supernatural forces. Accordingly, such men while meeting as best they might the demands of their tangible physical environment, felt that they could not afford to forget the demands of the world of spirits—the unseen environment.

The necessity of recognizing and making allowance for this additional factor was accentuated and made imperative by the belief that the aleatory element in life was somehow connected with it. There was the inexplicable in experience which was interpreted as due to spiritual agency, and primitive men sought to regulate the combination so far as they could. There was both necessity and attraction in attempting to do this. Necessity because angry spirits might harass and frustrate the most arduous efforts; attraction because of the possibility of something for nothing, results without labor, riches without toil, if only the spirits could be inveighed to use their limitless energies for human welfare.

With such an outlook on the problem of living early men strove for some method of dealing with the imagined environment. The effort took form in the cult. Schemes of every sort based on the spirit theory came into use, the purpose of which was to deal with the spirits. Avoidance, exorcism, prayer, propitiation, sacrifice,

[8] Keane: "The Botocudos," *Jour. Anth. Inst.*, 13, 108.

[9] Lippert: "Kulturgeschichte," I, 29.

magic, the medicine man and other institutions, the ensemble of which we call the cult, were developed as an adjustment to the additional environing situation.

Had the spirits been conceived solely as present but inactive it is unlikely that the cult would have become so prominent an institution in early societies. But, as early men viewed it, the spirits dominated the most characteristic aspect of the struggle for existence—the aleatory element. It was necessary to establish proper relationships with these agents who might hurt or help. The spirits being present and needing attention, the savage made it a part of his business in life to see that such attention was rendered. The cult became in this wise nothing more than one of primitive man's efforts to live as well as possible and arose as a regular part of the social organization for carrying on the struggle for existence. Primitive man having added to the terms of the struggle for existence could not be expected to employ an utilitarian method solely.

The Aims of the Cult

The accounts which we have of the cult objectives among uncivilized groups reveal that the agency of the religious organization was viewed as a part of the social mechanism for carrying on the business of living. Gomes states that "all the Dyak hopes to gain by his religious ceremonies is purely material benefits. A good crop of paddy, the heads of his enemies, skill in craft, health and prosperity."[10] Among the Koryaks of Siberia, "the Supreme being is propitiated for purely material reasons, such as the procuring of a food supply by hunting land and sea animals, the picking of berries and roots and the finding of reindeer herds."[11] MacDonald declares that "the Sikus, Lobos, Ijos every year make juju for the power to preserve their health, to prevent war and death, to maintain friendly relations with the traders and to bring good generally to the inhabitants."[12] The Eskimos told Rasmussen that they believed the magicians because they did not wish to expose themselves to famine and because they wished to live long. "We believe," they said, "in order to make our lives secure."[13] Such passages make clear that among primitive people the cult occupied a practical position in the life economy.

The Shaman

The reality of the spirit environment as primitive man conceived it, and the matter-of-fact way in which he accepted it and

[10] Gomes: "Seventeen Years among the Dyaks of Borneo," 204.
[11] Czaplica: "Aborigines of Siberia," 262.
[12] MacDonald: "Africana," I; 86.
[13] "People of the Polar North," 123.

turned it to his uses are conspicuously manifested in that important institution, the shaman or medicine man. His was an intensely practical function in the economic organization of early society. He provided a very essential means of adaptation as a means of approach to and control of the forces of the spirit world. So many were the features of the life of men coming within the range of chance, and hence according to early views under the influence of the spirits that it became expedient to select some one to specialize upon the matter. Indeed, there is here on the grand scale one of the first outstanding developments of the economic principle of the division of labor.

Among the Maori, the medicine man was supposed "to be able to interpret dreams, to explain prophecies, to cast out demons, to dissipate disease, and restore the body to health, to produce rain, to subdue storms, etc."[14] With the Malays, the Pawan "is a person of very real significance. In all agricultural operations, such as sowing, reaping, irrigation works and the draining of the jungle for planting, in fishing at sea, in prospecting for minerals, in case of sickness, in all his assistance is invoked."[15] Weeks says of the Congo negro that "the life of native, surrounded as he is by all these various spirits, would be intolerable, unthinkably so, were it not for his many witch doctors, who have power to control the spirits, and even to kill them."[16]

This brief view of the duties of Shaman indicates the exceeding value of his work. He was the specialist in the spiritual portion of the environment and in early society he was held to be as necessary as the blacksmith. Like the blacksmith also he was looked upon as a man who was prepared to perform a certain function a little better than any other person. If the malignant spirits were turning things topsy-turvy; if it was desired to take out an insurance policy against their future bad behavior, the Shaman was the man to whom to apply for aid. He was a public officer directing the group in its relation to its imaginary environment. His was a unique position; there is nothing like it in the story of mankind—a specialist in an imaginary field, upon whose offices it was believed that the success of the group in the struggle to live depended.

That his position in early society was regarded as practical in character is clearly evidenced in the fact that among many groups he had to obtain the desired results or lose his hold. Two citations will serve to indicate what may be shown to be quite regular among primitive groups. Among the Patagonians, Musters says "the po-

[14] Nichols: "The Maori Race," *Jour. Anth. Inst.*, 15; 199.

[15] Skeat: "Malay Magic," 57.

[16] Weeks: "Among Congo Cannibals."

sition of wizard or doctor is not a very desirable one, as in the event his prognostications on a war expedition or . . . in sickness, or any other event which is not realized, the chief will not infrequently have him killed.''[17] In South Africa, ''if, unluckily, one of these magicians happens to have predicted falsely several times in succession he is thrust out of the kraal, and very likely burned or put to death in some other way.''[18] What was demanded were results—practical working results, along with dependable predictions. If a man pretended to be a specialist in the spiritual environment and in the ways of the spirits he was tested by the results of the aleatory element in the group experience.

Sacrifice

The economic attitude of the uncivilized toward the spirits and deities is revealed also in their viewpoint in the matter of sacrifices. Propitiation, of course, may from our view of the cult be regarded as in the nature of social insurance against spiritual harassment in the struggle to get along. Sacrifice was a form of propitiation in the shape of material offerings to the spirits to satisfy their supposed hunger or greed. Such offerings, however, were not made gratuitously by primitive men. They were in effect like a cash payment for service rendered or about to be received; and their quantity, quality or value was regulated by the size and the character of the service desired. A few instances will illustrate the conduct of early men in their performance of sacrifice.

Schwannhauser says of the Dschagga, ''The sacrifice animals are exactly in accordance with the value of the desired-for benefit, costly or less so.''[19] That intrepid lady, Mary Kingsley, remarked, ''The value of the offering in these South West Coast regions has certainly a regular relation to the value of the favor required of the spirits.''[20] A similar notion prevailed among the Homeric Greeks: ''The sacrifices were in the nature of a contract, actual or implied, and in which one or both parties might be bound. In a regular bargain the sacrifice payment to the Gods was conditional upon their actual fulfilment of some request; in the other variety, the offering was made to the Gods *in the hope* that they would grant the request.''[21]

All the evidence available makes clear that sacrifices to the spirits by primitive men were payments and that no idea of renun-

[17] Musters: ''On the Races of Patagonia,'' *Jour. Anth. Inst.*, I, 203.
[18] Lichtenstein, ''Reisen im Sudlichen Africa,'' II, 61.
[19] Schwannhauser: ''Seelenleben der Dschagga Neger,'' 38.
[20] ''Travels in West Africa,'' 306.
[21] Keller: ''Homeric Society,'' 24.

ciation obtained. The Lolos of West China with some naïve perception of the nature of the case declared that such payments were blackmail.[22] In two modes sacrifice appears as a payment. Above all it was a neutrality toll—a bit of blackmail levied by the spirits in return for which they would keep their hands off human affairs. Again, it was a payment for good services, either to be rendered, or that may have been rendered. Blackmail or bribery both were fees gladly paid by early men. In this view sacrifice becomes a matter of precaution in life's everyday affairs. It was made a business proposition, payments in proportion to returns, received or anticipated.

The Cult as a Prosperity Policy

From what has been presented we are prepared to assert that in primitive social groups the cult and the struggle for existence were closely allied. The basis of this connection lay in the nature of early man's life experiences and his interpretation of those experiences. In ignorance of causal relationships in the scientific sense, and with, on the other hand, a developed set of illusions as to the spiritual character of his environment, it was simple for him to complete the structure in the endeavor to protect his material interests and provide for his necessities. He thus, taking cognizance of the spirits, went at the need in a practical, serious manner, and with very definite views as to what he expected to gain by so doing.

There is in the facts of the cult evidence of a tremendous group reaction upon a set of beliefs which had no basis in fact, but which, nevertheless, gave rise to institutions and to practices of profound social significance. The cult represents a case of adaptation to a non-existent environment, yet which was to early man as real as any of life's tangible factors. There was very little that was ethical or religious about all this, as we use the terms. It was the material needs and interests of men which induced them to introduce the cult into daily life. Truly, the primitive cult rested on a far more fundamental basis than that of a philosophical or theoretical morality. It was regarded as an actual factor in the struggle to live, as early men saw that struggle.

Bastian remarks in one of his works "that the heavier the burdens one puts upon the negro the more fetishes will he, on his side, add to compensate for the increase."[23] This would very naturally follow from primitive deductions as to the cause of trouble and care. Indeed, interpreting the facts of life as early men did, convinced that spirits lurked everywhere, awaiting an opportunity to

[22] A. Henry: "Lolos of N. China," *Jour. Anth. Inst.*, 23, 104.
[23] Bastian: "Afrikanische Reisen," 80.

thwart and harass, it is not surprising to find the proverb of the Bechunaa, "A man may not live without charms."[24]

This view of the cult makes clear many things which otherwise might baffle. Many of the practices which engaged primitive men in the cult were expensive and ruinous in their economic effects. It may not be believed that primitive men destroyed their capital, abandoned their growing crops and their houses out of mere caprice or foolhardiness. No man or group of men ever consciously set out to harm or impede their own life's interests nor to jeopardize life nor destroy their valuable property without reason. Heavy as were the burdens which his faith in spirits imposed upon him, early man held that he was doing the expedient thing. Attributing his vital concerns to the activities of spirit agency, he could not afford, whatever the cost, to neglect the spirits. The burden was acquiesced in that heavier burdens might not be imposed.

Early religion for these reasons presents no moral tendencies. Unless indirectly, it laid no emphasis on salvation or upon social ideals. At the outset, the religious organization came into view as a part of the business of life on earth. Early religious belief did not call for formal attention on stated occasions; it was an everyday consideration. In all things men did, in every interest in life the unforeseen forces might help or harass. Viewed negatively as a means of heading off disaster and positively as a means of helping things along, the cult represents a part of the prosperity policy of primitive groups.

[24] Garbut: "Native witchcraft and superstition in South Africa," *Jour. Anth. Inst.*, 39, 30.

LANGUAGE AS A FACTOR IN HUMAN EVOLUTION

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Of the many factors early affecting the change from ape-like to man-like creatures language is commonly admitted by students of human evolution to be one of the most important. Developing language was directly affected by the developing brain, and in turn reacted potently upon that developing brain. The superiority of human speech over animal speech, remarkably diversified as this latter often is, developed simultaneously with the growing human brain, of which it was partly product, partly cause.

At the same time that those wonderful ape hands were set free from duties of locomotion, through the change from arboreal quadrupedal locomotion to terrestrial bipedal locomotion, the ape brain was becoming human brain and the ape speech human speech. In fact, the freeing and perfecting of the hands was also part product, part cause of the developing brain and developing speech.

While we feel reasonably certain of these fundamental facts, it is pleasant to go a little further and to speculate as to the locality and the environmental conditions witnessing such changes. Present knowledge seems to point that it was somewhere in central or southern Asia, possibly just north of the Himalayas, mountains which are very new, geologically speaking, which, gradually rising to great heights, cut off the humidity from the sea to the southward, and changed the dense rain-forest to the north of them into more open park-like country. Many of the arboreal denizens of that forest were forced, in consequence, either to emigrate or to change their habits of life or to perish, and man was one of the species to change his habits of life, come down from the trees, gradually fit himself to combat numerous fierce foes in the open and acquire an erect, bipedal, terrestrial mode of life, using brain and hands continually in outwitting and destroying his animal foes and his prey alike.

Wherever the place, and whatever the environmental changes or circumstances which may have aided in this most interesting transformation, the fact remains that speech became humanized contemporaneously with the humanization of the animal brain and extremities.

The language of many animal species is, however, remarkable. Any person possessing good powers of observation, and living some length of time during childhood or youth in close proximity to domestic fowls, may readily learn to understand their language, the meaning of each sound they utter. Their language is quite diversified, and really remarkably ample, especially so when you consider the stupidity of domestic fowl. Their language was developed during their wild state, and passed on, partly by word of mouth (and syrinx), partly by instinct, generation after generation, to their less intelligent domesticated descendants, of every strain, the world over. Size, color, markings, laying ability and vocal timbre have been greatly changed through human selection, but they all speak the same language which he who learns may understand. Probably it would never have been developed to its present fulness if their feral ancestors had been as stupid, and had led as monotonous, safe and humdrum a life as our familiar chickens live to-day.

Our species of birds have their distinct languages, although some species are relatively silent. Mammals also have their various languages, and the different species of apes and monkeys are no exceptions to this statement; in fact, some species are distinctly and volubly chattersome. The human being of to-day, still considered a kind of ape by some zoologists, may likely have descended from a common ancestor of some of these volubly loquacious species. Further back, of course, all species of apes and man descended from a common ancestor, and yet further back all mammals from an early mammalian progenitor.

In the light of the common ancestry of all mammals and of all vertebrates in more ancient time, it is not surprising to find that certain sounds, ejaculations and tones are common property, not only to every mammalian tongue, but hence also to every human tongue or speech. Certain sounds denoting joy, grief, fear, distrust, amity and some other feelings are used by all tribes of men and by many mammalian species, and are understood by men of every tongue, without an interpreter, and by other mammals, having been passed down, partly by word of mouth, partly by instinct, from generation to generation of early, middle and recent mammals, including man.

In the little time that man has been in existence several distinct species of man have been evolved, but of these all are now extinct but one, being numbered with the vast multitude of extinct animal species, the long list of which grows prodigiously with each year of paleontological discovery. The one remaining species of man speaks hundreds of different languages.

The magnitude, elaborateness and diversity of our languages are due primarily to our unique proficiency and versatility in linguistic lines, made possible through the special development of the brain areas having to do with speech and thought, and secondarily through the specialization of certain vocal and other structures used in speech.

The great number of different languages spoken by different groups of men is due to man's linguistic proficiency and to geographical isolation of various groups. As all speech is continually varying, the speech of each isolated settlement would vary independently of each other settlement, producing a general divergence of the language of different sections of territory. After hundreds of thousands of years of isolation, broken by migrations small and large, we are at the present moment witnessing the origin and development of worldwide intercourse, progressing with wonderful rapidity.

How will this worldwide intercourse, soon to be consummated, affect language, which, as we have seen, is very sensitive, reacting to every stimulus; and how will the resulting unified language react upon the evolution of man in the future?

Let us return first to consider, very briefly, how language affected human evolution in the past, and then turn to its effect upon human evolution in future.

When man crossed the line which separates the genus Homo from his ancestral genus, which was when a particular strain of primates became, in the course of their evolutionary changes, sufficiently human to be called human, the change was marked primarily by the enlarged brain, highly specialized in those regions governing thought, speech and manual skill. His immediate pre-human ancestors had had remarkably good brains and unusual linguistic abilities, expressing through increased speech the increasing range of thought. The earliest father, mother and children of truly human standing were not exactly college graduates, but had graduated from the sub-human grades.

In somewhat the same sense that a boy about to enter college delights to call himself a sub-freshman, Eve's mother nursing little Eve in her arms might have been called a sub-human group. Eve had not grown up yet to demonstrate that she was really human. She was only, as it were, a rib in the side of her sub-human parents. She was probably very young when she married, for the way of nature is to marry young, and was, therefore, for a while, like a rib in her husband's side; as in her inexperience and mental immaturity she gradually opened, like a flower in the sunshine, under the influence of Adam's love, speech and experience, and finally demonstrated that she too was human.

In the early human families which followed, language grew by leaps and bounds, just as worldwide communication is leaping forward to-day. Every new thought called for a new word or a new phrase to express it. But a very important fact in this connection, and one to which philologists and evolutionists alike give great stress, is that words, phrases and expressed thoughts react upon the brain which coins them, and also act upon the brains of listeners.

All the objects in the natural world surrounding animals stimulate thought in those animals in proportion to the degree of intelligence possessed by the animal. Man, being superior in intelligence, was stimulated to more remarkable thoughts by these natural objects than were his inferiors in the evolutionary scale. But the acts and vocal expressions of his living companions are equally or more stimulating to the man or other animal. As these vocal expressions became more elaborate and more intense, keeping pace with the growing intellect, they became even more stimulating, both to the men who heard and also to the man who uttered. Each more advanced expression, each well-expressed idea was a new stimulus to that remarkable brain. So language grew with intellect and intellect grew with language; hand in hand they climbed the mountain, and helped each other up many a cliff and over many a dangerous chasm.

As side by side language and mind reached greater heights, now and then there opened up to them broader and clearer vistas of the world, and, in consequence, emotions of greater depth sprang into being. New forms of expression were needed to communicate the new emotions or new shades of old emotions, and the dawn of a concept of a world above, below or beyond the visible world was imminent.

It is quite clear that language has been a potent factor in human evolution in the past. From the very earliest beginnings of human existence to the present day it has, with brain and manual skill as the other two, constituted one of the three prime factors of human evolution, factors which are the intimate possessions of man himself rather than being factors belonging to his external environment.

The fact that language has been, from man's beginning to the present, one of the most intimate and effective factors in his evolution, affords very reasonable assurance that language will continue to be a prime factor in the further evolution of man.

Great care and thought and effort should be expended on our language of the present and near future, realizing how fruitful the results in molding the man of the future. In this connection consider the two great outstanding facts, that language is most plastic and continually changing and that we are at this moment in the

midst of the movement toward world communication, travel and intercourse, which is being developed with great rapidity, which the world has never witnessed before and which is likely to last as long as life lasts on earth. These two outstanding facts mean that there will be one world language to-morrow—probably within the lifetime of many even of the older readers of this paper and of practically all the younger folk.

What shall this world-language be? It is sure to be a boon to the world in any case.

The incidents of my own life, rather unique in some respects, have been such as to repeatedly impress upon me the similarity between language and shifting sands and changing shoreline. My father accepted a diplomatic appointment in Belgium resulting in our leaving America and living in Liége during the years of my early teens. There the official language of court and school was French, but many of the common folk spoke Walloon, a distinct branch of the Romance languages with a touch of Flemish and Low German. This combination was an eye-opener to an American boy who, in addition, had to translate his Latin lessons into French, and French to Latin, and began the study of Greek in French. The servants in the house—and most excellent ones they were—were from Maestricht, just across the Holland border, and spoke no English, only Dutch, French, Flemish and Walloon, being merely uneducated servants. After several years of this life we spent a whole year in travel and study in Germany, Switzerland, Italy, France, Holland and Great Britain. Later, in trips to Canada and the French, British and Spanish-speaking West Indies, and, shortly before the war, to Triest and the Karst Mountains in Austria, where languages literally by the half-dozen were on the tips of the tongues of the shop-keepers in every little store and dairy, I received ever new impressions of the endless variety and constant shift of the sands and tides on the world's linguistic shore. In Zürich I was told by an official in the forestry school that there are more than twenty distinct dialects in the German-speaking part of Switzerland alone, due, of course, to natural barriers in that rugged mountainous region. At present it happens that while most of my work requires the use of English, I also have to use some Spanish daily. A trip all over the world would ring endless permutations on the same theme, that language is like soft clay, being molded by factors within the man and in his surrounding environment, yet all the while reacting upon the man and his fellows. Languages come and languages go, but life goes on forever.

What shall the world-language be? Emphatically English, simplified and spelled phonetically, For some years it has been evi-

dent that English might become the world-language, but very recently it has come to appear almost inevitable. Men whose business interests encircle the globe are realizing this fact in advance of the rank and file.

English is spoken all over the United States, the most influential republic in the world. The British Empire includes well over one quarter of the land surface of the globe. Australia is about the size of the United States, and Canada is larger. The vast Indian and African possessions of the British will probably be English-speaking territory before long, and already, as the language of commerce, English is in advance of other languages. The people of China speak dialects not understood in all parts of China; their postage stamps are printed in Chinese and English. With the exception of some very small areas in which peculiar varieties of English are spoken, English is the same all over the English-speaking world, with only minor differences in accent and vocabulary, so that practically all English-speaking people understand one another without difficulty; which can not be said of most widely-spread languages.

English as a world language should be spelled absolutely phonetically to fit it for the use of continental and other people, as well as to simplify it for our own children. The changes in spelling should be no more radical than is absolutely necessary, yet wherever a radical change is imperative it should be in the direction of continental spelling. The number of different vowel sounds should be restricted, avoiding super-refinements in the pronunciation of different words when possible. The changes in spelling should be as few as possible, yet they should be sufficiently radical to make the rules of pronunciation very simple and so few that any one could become familiar with them in ten minutes. This will avoid the necessity of memorizing long lists of newly accepted spellings.

Without presuming to offer the following scheme of spelling to the world as its future language, I present below a simple illustration of the above-mentioned principles. It is offered simply as an example of what seems to be the simplest and easiest way for all people to spell English. The English language has some very strong advantages over other languages, as its simple treatment of the verb, its strict confinement of the masculine and feminine genders to things which are truly masculine or feminine, all other things being neuter, its splendid literature and the all-conquering aggressiveness of the English-speaking peoples.

a to represent 2 sounds: a as in cat, mat; ā as in are, Arlington, bar (ār, Ārlington, bār); replaced by o when having the sound o in or, lord: walk, awful, all, are ouc, oful, ol. The sound of ai in pair, air, is represented by

e: per, er. The sound of ai in pail, fail, is represented by ē: pēl, fēl. The sound of a in pale, tale, also represented by ē: pēl, tēl.

e to represent 2 sounds: e as in met, set, let; ē with the sound of ai in pail = pēl; to be omitted, 1. when silent, 2. when having the sound of e in er in butter, ermine, = bŏtr, rmin, 3. in final ed when not distinctly pronounced: sliced = slaisd, but sounded = sāunded, omitted = omited. *ee* pronounced as at present: meet, meat, sweet, are meet, meet, sueet.

i to represent one sound as in it, sit, fit; when sounded as in kite it is really a double sound, to be replaced by ai: cait, the personal pronoun I = ai, not egotistically to require a capital except when beginning a sentence.

o to represent 3 sounds: o in or, lord; ŏ in mŏnth, cŏvr, lŏvr; ō in clōvr, ōvr; replaced by ā when pronounced as in not, knot, how, cow, = nāt, nāt, hāu, cāu. oo as in boot replaced by *u*, but.

u to represent 2 sounds: u in true, blue, impromptu, = tru, blu, imprāmptu; ŭ in put, full, = pŭt, fŭl; preceded by i when pronounced as in cute = ciut, a double sound.

w and *y* are not needed. Every silent letter omitted. Consonants not doubled. Hyphenated words made compound by dropping the hyphen.

c hard; replaced by s when soft.

ch as in church; replaced by c when hard, and by *sh* when so sounded: chimney, chemistry, chemise, = chimnee, cemistree, shemees.

f as in fit; replaced by *v* when so pronounced: of = ŏv; replacing gh when so pronounced: rough = rŏf.

g hard; replaced by j when soft.

ng as at present: sing. *k* and *q* not needed. *r* as at present.

s as at present, and replacing soft c, but replaced by *z* when so pronounced: is = iz. *sh* as at present, and sometimes replacing ch: chemise = shemees.

t as at present, but replaced by ch when so pronounced: substantial = sŏbstanchal.

x as at present, but replaced by *z* when so pronounced.

z as at present, and replacing s and x when these are so pronounced.

More examples: "Though the rough cough and hiccough plough me through," would read "tho thee rŏf cof and hicŏp plau mee thru." "Xenophon knows how to play the xylophone but prefers the flute;" Zenōfŏn nōz hāu tu plē thee zilōfōn bŏt preeferz thee flut. At present he receives six per cent. on his money; At prezent hee reeseevz six prsent ān hiz mŏnee.

The Lord is my shepherd, I shall not want. He maketh me to lie down in green pastures; he leadeth me beside the still waters; he restoreth my soul.

Thee Lord iz mai sheprd, ai shal nāt uant. Hee mēceth mee tu lai daun in green paschurs; hee leedeth mee beesaid thee stil uoters; hee reestoreth mai sōl.

Whoever helps the spread of English as a world language will aid world inter-communication and hasten human evolution. Whoever helps to refine the language by using the choicest and most beautiful expressions and words, and avoiding consistently all cheap, foul or vulgar expressions, will aid in guiding human evolution in the right direction, since language continually reacts on the speaker and hearer.

JOHN T. GULICK, A CONTRIBUTOR TO EVOLUTIONARY THOUGHT

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ONE more of our few remaining ties with the initial period of Darwinian thinking was severed by the death of Dr. John T. Gulick, on April 14th, 1923. He was born in the Hawaiian Islands in 1832, the son of a missionary, and his early years were spent in that region. As a youth he travelled in Oregon, dug gold in California and visited the Gilbert and Caroline Islands. Among the papers he has left is a very unique diary of these experiences, in which can be traced the development of his intense fondness for natural history. It was his good fortune to become acquainted in 1853 with Darwin's "Voyage of the Beagle," and with Hugh Miller's "Footprints of the Creator." He was greatly impressed with Darwin's description of the localized species of birds and reptiles in the Galapagos Islands, and at once began to make comparisons between the facts which Darwin presented and facts that he could observe for himself in his own islands. Hugh Miller's book was a presentation of the main outline facts of paleontology, together with an exposition of the principal theories of evolution previous to Darwin, and an argument intended to refute evolutionary doctrines.

Under these influences he devoted his major energies during 1853 to systematic and thorough collecting of the land snails of the Island of Oahu, Hawaii. The conviction had grown up in his mind that written upon the very form and structure of these Hawaiian shells was a marvelous self-revelation from the hand of the Creator Himself, and that if we could but learn the alphabet we might read from them the story of his method of creation.

John Gulick had selected foreign missionary work to be his life profession, following the example of his father. He prepared himself in Williams College (class of 1859) and in Union Theological Seminary, and then found his way in 1862 to the Orient. The first two years he was in Japan, a country that was hardly yet really open to foreigners. After that he was stationed in North China until 1875, and from 1875 to the time of his retirement in 1900 he was a member of the Congregational Mission in Japan. The last 17 years of his life he resided in Honolulu.

Gulick was one of the small group of Americans to be promptly and completely convinced by Darwin's argument when the "Origin

of Species'' first came into their hands in the winter of 1859–60. And, indeed, the broad concept of evolution through descent was but an easy step forward from the opinion towards which he had already been inclining for several years that ''many genuine species had been derived by descent from one original stock or species.'' But he did not feel that all the problems had been solved, and throughout his whole career he spent much thought in analyzing his data from Hawaii. The first published fruits of this analysis are found in *Nature,* July 18, 1872 (''The variation of species as related to their geographical distribution, illustrated by the Achatinellidae'') and in the *Journal* of the Linnean Society, London, Vol. 10, 1872 (''Diversity of evolution under one set of external conditions''). Further contributions were published in the same journal in Vol. 20, 1887 (''Divergent evolution through cumulative segregation'') and in Vol. 23, 1889 (''Intensive segregation''). His most serious presentation of the whole subject is the book, ''Evolution, Racial and Habitudinal,'' published in 1905 by the Carnegie Institution of Washington. A number of minor papers appeared from time to time in *Nature,* the *American Journal of Science,* and the *American Naturalist.* Of his papers on other subjects, religious, linguistic and the like, we need only mention here his article on ''Christianity and the evolution of rational life,'' appearing in the *Bibliotheca Sacra* for January, 1896, in which is published the correspondence upon the subject of religion which he had with the English zoologist, G. J. Romanes.

The contributions which Gulick made to evolutionary theory had their starting point in his observations upon the land snails of the Hawaiian Islands, and more particularly the forms found upon Oahu, the island on which Honolulu is located.

The great bulk of the Hawaiian snails belong to a family not found elsewhere. Although broadly related to each other, they are divisible into two or more sub-families possessing a number of genera and a host of species. The majority of them live in the leaf mould of the perennially damp forests, and are able, in a limited way, to travel about over a forest area. But contrasted with these is one whole subdivision, the Achatinellidae, the species of which all have their permanent abode at a higher level above the ground, upon the trunks, branches and leaves of the forest growths. The very numerous species of this beautiful group are quite diverse in size, shape and shell texture, and are besides decorated with brilliant hues of green, pink, red, brown, black, straw and porcelain white, laid on in variegated patterns of spiral bands and flame marks. As compared to other land snails they are fairly active creatures, apparently rather short-lived, and probably fairly rapid

reproducers. In their natural haunts they cull their nourishment from the thin film of algae and fungi on the bark over which they wander. But they are not squeamish feeders, and in laboratory they will eat liberally of almost anything that has the right physical consistency—banana peel, for example, or even wet paper.

These Achatinellidae have their power of migration limited to a very extraordinary degree by their special manner of life. They are never seen coming down and crawling across from one tree to another, as the garden helices do in Europe. They bear living young which are able to cling to the trees from the start, and take care of themselves in much the same manner as when adult. They do somehow spread themselves from tree to tree, and have even become abundant in some places on groves and thickets of foreign plants, such as the guava, that have been rather recently naturalized. But still their power of dispersal is so slight that when a tree falls to the ground, the greater part of its snail colony appears to perish along with the mouldering log.

The forest belt in which they are distributed is not continuous, but consists partly of small groves and isolated thickets located in the brook gulches on the sides of the mountains, and partly of the dense tangled shrubbery of the higher summits, separated from each other by precipices and knife-edge divides. The lowlands into which the brook valleys open out have neither the trees nor the moisture to support an Achatinella. A strip of grassland or a well-developed escarpment can produce as complete an isolation among these snails as would be caused for most animals by a continental range of mountains. But while animal populations on opposite sides of the Alps or the Rockies may be expected to face different environments through the diversity of climate and of food plants, the isolated colonies of these snails, separated perhaps by only a quarter mile of treeless ridge, or a half mile gap of grassy lowland, were certainly living under practically identical environments in all their different groves.

Gulick saw in this as it were an experiment, performed by Nature herself, to demonstrate what would happen in the evolution of a species, if it were broken up into little colonies, each of which was closely isolated in its own little precinct, where its environment was just about like that in all the other precincts. Darwin had shown that the environment, by selecting the individuals that best fitted it, and eliminating the rest, would exert a sort of outside compulsion, forcing all the animals in one environment to evolve in one direction. But the actual evolution of the snails in this great natural experiment had been in diverse directions, proving that there is more happening in evolution than the factors discovered by Darwin can account for.

Speaking to a Honolulu audience at a comparatively recent date, Gulick said:

> Each valley on Oahu was occupied by some peculiar forms. Valleys only a mile apart were occupied by distinct varieties, and sometimes different species. Groves of the kukui [or candlenut tree] in valleys five or six miles apart were found to be the homes of completely separate sets of species. Standing on Roundtop [a hill which overlooks Honolulu], I could say, in this valley of Makiki, on the west side of this hill, is the birthplace of *Achatinella producta* and *Achatinella adusta;* and in Manoa, on the other side of the hill, were created *Achatinella johnsoni* and *Achatinella stewartii;* while a mile to the northeast, in the jungle that clings to the almost precipitous cliffs on the other side of the backbone of the island, is the home of the very rare and beautiful species *Achatinella versipellis.*

Had he chosen, Gulick might next have transferred himself in thought to some other hill two or three miles distant and pointed out other equally striking assemblages of forms. The most noteworthy spot is perhaps the north west wall of Nuuanu Valley, a short distance back of Honolulu, where C. Montague Cooke has studied the close localization of 25 color varieties of *Achatinella vulpina* in the different parts of a collecting belt that extends only about one mile, with a width of 100 to 400 yards.

In general every grove has a considerable variety of color patterns, and some variability in size, shape and texture. Neighboring groves reduplicate a share of these patterns, but are likely to introduce some new note. Groves further along have progressively more and more such new notes, and fewer old notes. Some of the color patterns are relatively persistent, ranging over the groves of several entire valleys; others are so local as to be known only from a single "pocket" or cluster of trees.

Another prominent fact is the breakdown of the old concept of "species," when applied to the Hawaiian snails. It is a familiar thing nowadays that in young, rapidly evolving genera of plants and animals no one can say categorically, "These two forms are varieties of one species, but those two forms are two distinct species." On the old theory that each species was separately created, it was supposed that no such separate creation would intergrade with any other species, and the absence of such intergrades was looked upon as one of the necessary criteria for "good" species. But if species are merely varieties which have grown away from each other till it is no longer fitting to call them the same, then there can be no such simple way to define the moment when they cease to be "the same" and become "different." Incipient species of a rapidly evolving genus are likely not only to be bewilderingly similar, but also to further confuse the classifier by presenting intermediate forms that link all the different species to each other.

In a few cases a particular species of *Achatinella* seems to be well marked off from its nearest relative, as a result of the extinction of the varieties that must have been in the intermediate valleys lying between it and the home of its nearest relative. Supposing we willfully extended this process of exterminating the intermediate colonies by burning out a couple of miles of forest here and there, we would certainly be increasing the number of separate groups of forms that were free from intergrades, and making it easier for the systematist to define these "species." But surely the number of kinds of snail is quite as great before the destruction as after. Gulick often spoke of this proof of the breakdown of the old species concept. In his own naming of species he gave different names to any forms that seemed to differ with a fair degree of constancy, and those less numerous individuals that bridged the gaps between the more abundant and important typical forms he frankly designated as intergrades or connecting links.

These commonplaces of modern biology were not recognized in 1850, and Gulick was among the first of scientific zoologists to observe them in actual wild life.

The information gained in the last quarter century regarding laws of heredity has thrown these early observations into a somewhat different perspective, but I believe without diminishing their importance. In particular, people of the 19th century were inclined to assume that cross-breeding of two forms produced offspring with an intermediate appearance. We now know it is possible for the mixed population to be devoid of intermediate examples, and composed entirely of individuals that appear to be uncontaminated examples of the one or the other parental stock. Applying this to the Hawaiian snails, when Gulick observed in Manoa Valley the two contrasted forms, *Achatinella johnsoni*, with its incisive and reasonably constant color pattern of very dark and light spiral bands, and *Achatinella stewartii*, in which the broad ground color of buff or brownish green is only interrupted by one narrow line of darker pigment, it was impossible for him to consider them the same kind of snail. Sorting them into piles it is instantly obvious that they are two definite and different things. But collectors on the grounds to-day know that wherever *johnsoni* is found, it lives together with *stewartii* as a single indivisible population. It seems likely that they differ from each other by factors that are inherited in an alternative, that is to say, a more or less Mendelian manner, and so, although the student of evolution must continue to think of them with their differences, he must approve of the systematist's action in denying to *johnsoni* even the dignity of a variety in the taxonomic sense. This is just an illustration. Many of Gulick's "species" are nothing more nor less than out-

spoken color forms which a person might perhaps develop into "pure lines" by laboratory methods, but which do not exist in nature as self-maintaining populations, and very likely never did. The genetic formulae of none of these forms have ever been worked out through experimental breeding, but if this is ever done, the formulae for color and pattern inheritance will probably be very complex.

It is worthy of note that although so many of Gulick's old "species" are now called "varieties," "mutants," "color forms," etc., the assemblages that are still regarded as "species" by the modern taxonomist have an extremely local range. The Koolau Mountain Range on Oahu Island, for example, although only about 30 miles long, has 14 species of the subgenus Achatinellastrum alone, each with a geographical extent of from 2 or 3 up to some 12 miles. The average distance between the easternmost and westernmost colonies of each species is only about 6.5 miles. Each of the other subgenera would tell a similar story.[1]

Taken all together, this snail fauna is more suggestive of a diminutive continent than of an ordinary island. Imagine a mountain range 1,000 miles long, supplied with an ordinary fauna of snails—some of its species distributed along perhaps a third of the length of the whole mountain chain, but a good many local species spread to cover scarcely farther than one tenth of the chain. Then imagine these mountains shrunk till they extended only 30 miles, everything still to scale, so that every 100 miles of the original is now represented by only 3 miles, and imagine that every species of snail inhabits only the miniature district which this process leaves for it, and you will then have a very good picture of the chief mountain range of Oahu, with every little ridge and valley occupied by some distinctive and absurdly localized form of snail.

The cause of all this multiplicity could not be the external environment, because a uniform cause can not account for diversity of evolution. So by elimination Gulick concluded that the snails must be showing a spontaneous tendency to change their average characteristics, and that in no two colonies did this tendency lead in exactly the same direction. Where great numbers interbreed as a single population there might be many such tendencies represented, but a large share of them would be neutralized by the intercrossing of opposite traits. But in a little group of individuals there could not be so many tendencies represented by the limited number of reproducing parents, and whatever tendencies happened to be on hand would be far likelier to reveal themselves unhindered by crossing with any reverse tendency. Thus a big compact popu-

[1] See H. A. Pilsbry, "Manual of Conchology," Vol. 22.

lation does not quickly change the average of its characteristics, while isolated colonies numbering only a few individuals apiece have an unlimited opportunity to blossom forth into any novel form towards which their unstable heredity may trend.

So the unusually extreme subdivision of this land snail population into tiny, closely isolated colonies opened the way for an astonishing display of the inherent tendency to vary progressively in sundry directions almost without limit, a tendency that is universal among living creatures, but is generally held in check by free intermingling. This led Gulick to place great emphasis upon every form of isolation or prevention of mingling, and also to emphasize the great significance for evolution of many factors that are of internal origin, such as the unknown intricacies of the process of heredity, and the effects of new choices made by the evolving creatures, which may lead them into new situations and subject them ultimately to an entirely altered trend of natural selection.

In his largest work, "Evolution, Racial and Habitudinal," Gulick followed a somewhat formal dialectic treatment by which he could make a technically exhaustive enumeration of the factors of evolution. This manner of treatment is a little foreign to the average scientist to-day, but it has its own great value, particularly as a method of mapping out the whole field of the subject, and making obvious in what portion of the field to look for new scientific discoveries.

He pointed out a limited group of conditions that every sexually reproducing species of plant or animal must fulfill in order to be broken up by evolution into a diversity of species. Obviously its reproductive power and ability to survive in its surroundings must be sufficient to keep it from being exterminated. But also it must have what we call heredity—the power to maintain the essentials of its type, and variation—or the tendency for individuals to show tentative changes in the hereditary type. To these points, which every evolutionist admits, Gulick added those which constitute the essence of racial segregation—the breeding of like with like, to the exclusion of others which are unlike, or which are on the road to become unlike. The factors in this racial segregation, he analyzes as, firstly, the different forms of isolation (of which geographical isolation is the simplest, most obvious illustration) and, secondly, the different forms of unequal survival, such as natural selection. When natural selection intensifies the initial differences between two segregated populations, he calls the result intensive or cumulative segregation, the outcome of which is divergent evolution.

But transformation of race is not the whole of evolution. Civilization also evolves, and in lower animals there is an evolution of

habitudes, that might be viewed as a rudimentary counterpart to the evolution of civilization. Gulick points out that this habitudinal evolution is exceedingly important, because it is perpetually changing the trend of natural selection, and thus influencing the direction taken by racial evolution. His tabular review of habitudinal evolution has much similarity to the racial. In place of reproduction is here the power to obtain imitators or pupils. Tradition is the counterpart of heredity, innovation or inventiveness the counterpart of variation. Segregate association here plays the corresponding rôle to segregate breeding (or racial segregation). And, finally, to the cultural analogs for selection and survival he gave the names of election and success.

The only factors in divergent evolution that he worked out in detail were those that have directly to do with segregation. Even selection, although it is one of the great causes that intensify segregation, no longer needed an exhaustive presentation, after the controversies that had centered about it ever since 1859. And as for heredity and variation, so little was known at the date of his writing —the rediscovery of Mendel's laws came just as Gulick was beginning to prepare his book—that he judged it much the soundest plan to leave their principles practically undiscussed. He did not join in the controversy about the "inheritance of acquired characters." When he used the term "acquired characters" he almost always meant the changes in skill and in tastes that come from habit, education and the like. This variety of acquired characters he discussed repeatedly in their relation to habitudinal evolution. Mendelism interested him intensely, but he felt that it comprised a research field for the younger generation rather than a topic for his own discussion.

The careful reader of Gulick's book on evolution will note a continual emphasis upon the spontaneous or "voluntary" activities of the evolving animals, and at the top of the evolution series a stressing of the evolution of social and moral qualities, including those most remarkable and supremely important phases of human evolution, the development of altruism, cooperation and regard for the general good. In his last years this aspect of evolution and its practical application to human affairs claimed his interest above all the other phases. Every person will recognize that in this practical field there will be the greatest conceivable diversity in the opinion even of those evolutionists who hold closely similar views regarding the forces at work in biological evolution. Gulick's expressed belief was that the outstanding practical problems in the evolution of civilization to-day are the development of the principle of cooperation, of genuine equality in the opportunities for accomplishment,

and the establishment of motives for serving the community that will be less antisocial than are the selfishly competitive motives which too often rule in these days. He believed further that the world is practically without any political group that is seriously grappling with the last of these problems, and that the State Socialists are the only party with any reasonable solution of the first two points—indeed the only ones (unless it be the communists) to have attempted any answer at all. Some of his latest articles deal with his thoughts on this problem.

In these days of supposed conflict between religion and modern science it is worth recording that throughout his life the motives that inspired Gulick to study the processes of evolution were always deeply religious. It was in a spirit of loyal reverence for the Great Creator that he sought to learn something of the process of creation that is still going on. And it was always with a thrill of awe that he contemplated any great valid generalization, whether it be in biology, social science or mathematics. As a missionary his reputation as a constructive scientist was his greatest asset, since it won for him a degree of respectful attention from the highly educated Japanese that they would otherwise seldom give to a religious teacher.

In his lifetime John Gulick spanned one of the world's greatest periods of conflict between modern science and the reactionary exponents of ecclesiastical dogma, yet he never lost the sense of harmony between scientific truth and religion, and he inspired many other men with the same sense of harmony.

THE GROWTH OF THE TELESCOPE[1]

By Major WILLIAM J. S. LOCKYER
DIRECTOR, NORMAN LOCKYER OBSERVATORY

I PROPOSE to-night to give you a brief history of the development of the astronomical telescope. The story is a very long one, but I hope in the short time which I have at my disposal to make you acquainted with at least some of the main features of the progress.

I want you first to picture to yourselves living in the beginning of the year 1608, that is 315 years ago, or about ten generations ago. At that time telescopes did not exist. When you looked out at the night sky you would see the stars, as you do to-day, of various brightnesses, and occasionally the moon exhibiting different forms. A more careful look on consecutive nights would indicate to you some bright star-like bodies or "wandering" stars, which change their positions with reference to other stars, and which thus behave quite differently to the stars in general. By day you would see the sun and sometimes the moon also.

If you wished to study these bodies all you could do would be to observe their motions in relation to each other. You could see nothing of their details.

The main work of astronomers before the year 1608 was therefore concentrated on observing and recording the positions of the heavenly bodies from day to day and from year to year. And this was all.

With regard to the importance of recording the positions of the stars, the planets, the moon and the sun there is no question, because it was only by knowing their positions at some epoch that their subsequent relative changes could be determined. Thus, for example, we can forecast very accurately to-day the eclipses of the sun and moon, occultations of the stars, etc.

Again, by the knowledge of star positions accurate determinations can be made of the exact position of any spot on the land or sea, so leading to the formation of a very precise map of the earth's surface.

Observations of this nature led up to the formation of ideas about the celestial system, and it was by means of these that it was discovered that the earth rotated on its axis, that the earth revolved round the sun, that the planets revolved round the sun, that the moon revolved round the earth, and such like fundamental facts.

[1] Address delivered before the Royal Institution of Great Britain on April 20, 1923.

The early observer of the night sky would have noticed that in mid-latitudes there were some stars which never rose or set, but which moved round a point in the heavens known as the celestial pole, while others rose and set, only portions of their daily paths being visible.

To determine the position of any star he would have to measure its angular distance from the pole (North Polar Distance) or from the celestial equator (Declination), and also its angular distance from a plane passing through the celestial pole and a fixed point on the celestial equator (Right Ascension). Another method would be to measure the angular distance of the star from the horizon (Altitude), and its distance from the meridian or plane passing through the Zenith and true north and south points (Azimuth), together with the time of observation.

The early (1587) instruments for observations of position took the form of graduated quadrants mounted in a vertical plane capable of rotation about the center of a horizontal divided circle. The direction of a heavenly body could only be indicated by pointing at it, so every quadrant was furnished with a pointer pivoted at the center of the quadrant. The adjustments of the instruments were made by using a plumb line for the determination of the vertical and a level for placing the azimuth circle horizontal.

Tycho Brahe, the famous Danish astronomer (1546–1601) constructed many elaborate instruments of this nature for his observatory at Uraniberg, but his most important instrument was the large quadrant fixed in the meridian with which he observed transits of the heavenly bodies through a hole in the south wall. This instrument was the forerunner of the modern transit circle.

The telescopic era commenced in the year 1608, when, so history relates, an apprentice of Lipperhay, a spectacle maker at Middleburg in Holland, accidentally placed a double concave lens between his eye and a double convex lens. Observing the weathercock of a neighboring church he found that the object appeared magnified and upside down. Lipperhay, grasping the novelty of this lens arrangement, mounted the lenses in tubes, thus making the first telescope, and placed the instrument just at the door of his shop to amuse his customers. The Marquis of Spinola, then at The Hague, bought this "optik tube" and presented it to the Archduke Albert of Austria, and it was chiefly in this way that the news of the invention spread abroad.

Galileo, who was in Italy, hearing of the discovery, proceeded in the following year to make one himself, magnifying seven times. Galileo was the first to use the "optik tube" for the study of the heavenly bodies, and in consequence made a series of important

discoveries with his tiny telescope. Thus he found that the number of stars was enormously increased, the "wandering stars" were really planets, the moon displayed mountains, Jupiter possessed a family of satellites, Saturn exhibited curious features which were eventually identified as a ring system, Venus appeared as a crescent, spots were visible on the solar surface, etc. His discoveries altogether strongly supported the system of Copernicus.

The lens combination employed by Galileo underwent changes as time advanced. In 1620 Kepler suggested the use of two double convex lenses, and this was actually carried out by Scheiner in 1637.

One had to wait nearly a hundred years before Chester More Hall in 1733 put forth the idea of making an object glass of two different kinds of glass, crown and flint, placed close together, thus establishing the so-called "achromatic lens." It was not, however, until another quarter of a century had passed that John Dollond in 1758 rendered this discovery effective, thus heralding the dawn of what may be termed modern astronomical observation.

In the year 1639 the discovery of another form of telescope was made—namely, the reflecting telescope—but it was not until the year 1663 that the principle was described in practical form by James Gregory. It was left, however, to Sir Isaac Newton in 1668 actually to construct an instrument of this nature, and the telescope he made, which is quite small, is to-day in the rooms of the Royal Society of London.

Like the refracting telescope, the reflecting telescope underwent various changes in the optical train; thus we have the forms now known as the Newtonian, Gregorian, Cassegrainian and Herschelian.

As soon as the refracting telescope became a practical instrument it was at once brought into commission for instruments employed in the measurements of the positions of the heavenly bodies. In fact, it at once replaced "pointers."

Tycho Brahe's great quadrant was soon superseded by a type of instrument similar to that made in 1770 by Sisson for the Kew Observatory. This was an eight-foot quadrant, mounted in the meridian, with a finely divided scale and vernier. The quadrant form later developed into a complete graduated circle read by several microscopes after the type of Gambey's mural circle made in 1819 for the Paris Observatory.

The acme of perfection in accuracy is reached to-day by such an instrument as the present Cape Observatory transit circle. In this the telescope has an objective of six inches aperture of the finest construction, two very finely graduated circles are attached and several micrometers are employed for reading each circle. Many

other refinements, too numerous to be mentioned here, are included to attain the highest accuracy.

In order to follow the developments of the two kinds of telescopes—namely, the refractors and reflectors—it is best to deal with each kind separately, so the former type of telescope will be first considered.

Returning to the epoch many years before John Dollond made the achromatic lens effective, it was found that an object glass, which then consisted of a single lens only, formed images at the focus which were highly colored and spoiled definition. The only method of securing greater magnifying power, with increase of aperture or diameter of lens, was to make the lenses of great focal length, for experience had shown that the greater the focal length the less the color.

Thus, about the year 1680, we come to the age of giant telescopes, when their lengths measured anything from 60 feet to 210 feet. These cumbrous instruments were generally suspended by their middle from tall masts or towers, and to reduce their weight diaphragms placed at stated intervals took the place of wooden tubes. Thus were the telescopes of Hevelius. Huyghens adopted the novel principle of only placing the object glass on the mast, the eyepiece being attached to it by a long cord, which could be stretched tight and so make the proper optical alignment.

An illustration of a giant observatory of Hevelius' time given here (Fig. 1) displays three of these long telescopes in use. Mechanism is shown by which not only can the telescopes be hoisted into position, but which is capable of turning round the roof of the tower to which the telescopes are suspended to neutralize the earth's motion. The illustration shows that even in those days a considerable observatory staff was necessary.

There is no doubt that a telescope can not be properly manipulated unless it is equatorially mounted—*i.e.*, mounted on an axis inclined to the latitude in which it is used. One of the first, if not the first, telescopes to be set up in this manner was that used by Scheiner in 1618 for observing the spots on the sun. Scheiner had only to direct the telescope to the sun, and fix it in declination, when the diurnal movement could be compensated by simply moving the telescope westward by hand. The form of mounting he adopted was the foundation of the German type of mounting telescopes, to which reference will be made later.

Not only is it imperative for a telescope to be equatorially mounted, but it must also be driven by some power, clockwork or otherwise, so that the object under observation will always remain in the center of the field of view of the telescope.

Hooke, so far as is known, was the first to adopt this principle in 1674. As is indicated in an old print of his instrument, he mounted his quadrant at the upper end of a long polar axis, and rotated this by means of gear wheels actuated by a falling weight. The speed was controlled by a conical pendulum governor, which could be shortened or lengthened at will.

We had to wait, however, until the year 1823 before a really efficient driving clock was applied to a telescope. This was the work of Frauenhofer, and adapted to the 9½-inch Dorpat refractor, made for the Czar Nicholas of Russia, the largest refractor of that period.

The principle is the same as that used to-day: the clockwork driven by weights, and controlled by a governor actuating a tangent screw, which is in gear with the threads cut in the circumference of the driving circle, to which the telescope can be clamped.

The Dorpat instrument may be said to be the first real modern refractor, as it embodied all the fundamental features of telescopes constructed afterwards.

The refracting telescope having reached this efficient stage, a rapid survey only is necessary to indicate the growth, as this depended simply on the capacity of opticians in making large object glasses.

Reference may first be made, however, to the methods of mounting telescopes in general, because not only do the completed instruments look very different, but some forms are more convenient than others for certain purposes.

There are three well-known recognized forms illustrated in Fig. 2, and termed the "English," "German" and "Composite" types.

In the "English" type the telescope tube is mounted directly on the polar axis midway between the supports of this axis, and being symmetrically placed balances itself both in Right Ascension and Declination. The "composite" type is rather similar to that of the "English," only the tube is placed on one side of the polar axis, and the counterpoise weights on the opposite side. In the "German" type the tube, with its counterpoise weights, is fixed symmetrically to the prolongation of the upper end of the polar axis—that is, outside the supports of this axis. There is still a more modern modification of the "German" type, in which the polar axis is prolonged at its upper end, taking the shape of a fork. The telescope tube is placed symmetrically in this fork, thus obviating the necessity for counterpoise weights.

Coming now to the advance in telescope construction, time permits one only to *mention* such instruments as the 15-inch Pulkowa (1839), by Merz and Mahler, the 16-inch Harvard (1847), also by

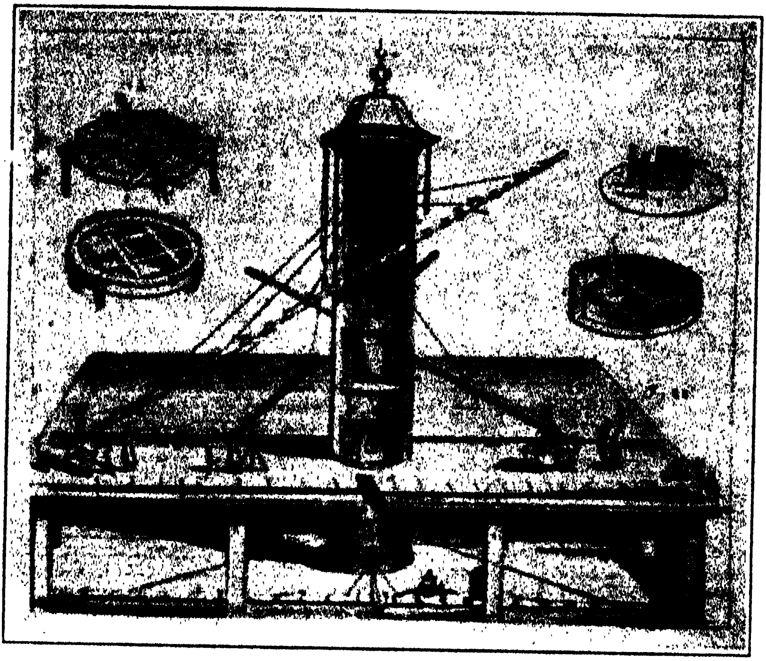


FIG. 1. HEVELIUS' AERIAL TELESCOPES
Mounted by suspension from the roof of a tower, which can be rotated by gear-work.
[From Hevelius, "Machina Celestis."]

Merz and Mahler, and the 18-inch Chicago University telescope (1862), by Alvan Clark.

The year 1868 saw the completion of the fine 25-inch made by Cooke for Mr. R. S. Newall's Observatory at Gateshead. This instrument, by far the largest of its day, was mounted after the "German" form. It had a focal length of 30 feet, so that the dome and observing chair had to be of great proportions. So satisfactory was the behavior of this instrument that, after a journey to this country to inspect this telescope, the representatives from the Washington Observatory ordered a 26-inch of 32 feet focal length from Alvan Clark, which was completed in 1873.

In 1880 Grubb surpassed this size by making a 27-inch for the Vienna Observatory, but five years later (1885) Alvan Clark turned out a 30-inch objective of 42 feet focal length for the Pulkowa Observatory. The following year (1886) saw another objective of the same size constructed by the Brothers Henry for the Nice Observatory, but this was soon eclipsed by the completion in 1887 by Alvan Clark of the Great Lick Refractor of 36-inch aperture and 57 feet focal length, erected on Mount Hamilton, in California.

For this instrument an observing chair, as such, had to be

abandoned, but the floor of the observatory was made capable of elevation and depression, thus sweeping away many difficulties and adding many facilities.

Two large telescopes, though not records in size, followed the construction of the Lick instrument. The first was the 28-inch of 28 feet focal length by Grubb (1893) for the Greenwich Observatory, mounted after the "English" fashion. This is the largest refractor in this country to-day. In the following year (1894) the Brothers Henry completed the 32-inch 53 feet focal length telescope for the Astrophysical Observatory at Meudon, near Paris.

The largest refractor in the world to-day—namely, the Yerkes telescope of the Chicago University—was completed in 1895, the object glass, by Alvan Clark, being 40 inches in diameter and of 62 feet focal length. It is mounted very similarly to the Lick instrument, and fitted with all the latest facilities for assisting the observer at the eye end, including a rising and falling floor.

Fig. 2. The Three Main Methods of Mounting Telescopes

In mounting large refractors the standard forms have occasionally been departed from in order to attain some special end. These may be termed "novel" forms, and four examples may be mentioned here.

Thus, at the Paris Observatory, there was erected in 1890 a 23½-inch objective of 62 feet focal length in a tube mounted in the "Condé" form, after the design of Monsieur Loewy. This instrument is so constructed that the observer is housed in a comfortable room in which the eye end of the telescope is suitably fixed, and he can observe any object in the heavens without moving from his chair by means of reflections from two mirrors in the peculiar shaped tube after the light has passed through the object glass.

Another novel form was exhibited at the Paris Exhibition of 1900 to utilize an object glass of 49 inches aperture and 197 feet focal length made by Monsieur Gautier.

In order to avoid the necessity of having to move such a heavy object glass and tube, the principle that was adopted was to place the telescope horizontally in a true north and south position with the object glass facing north. The light from any celestial object was then reflected into this tube by means of a large silver-on-glass mirror mounted as a siderostat and moved by clockwork. This particular telescope has never been effectively used, so in spite of its great objective it has not been classed as the greatest telescope of to-day.

A curious mounting is that employed for the 27-inch telescope of 70 feet focal length of the Trepstow Observatory, near Berlin, erected in 1909. The main object in the construction was to obviate the cost of a large dome and rising floor, and also to make the eyepiece of the instrument very easy of access for numerous visitors. To accomplish this the tube was erected on the modified "German" type of mounting in such a way that the eye end of the tube should be situated just above the upper end of the polar axis. The tube was counterpoised in declination by two great weights placed at the extremities of two long arms extending northwards and symmetrically placed as regards the tube. There the eyepiece was in the center of motion of the telescope and practically stationary for all positions of the tube; also by simply setting the tube near the position of horizontality it could be covered by a light wooden low structure.

The last novel form of mounting to be mentioned was erected in 1912, and is known as the 150-foot Tower Telescope of the Mount Wilson Observatory. Its origin developed from the fact that an objective of long focal length was required to be used in conjunction with a spectroscope also of long focal length.

Previous experience had shown that air currents near the ground affected the definition when such long instruments were used in a horizontal position. Dr. Hale conceived the idea of mounting the object lens high up on a metal girder tower and throwing the images of the celestial object to be studied vertically downwards on to the spectroscope placed vertically in a shaft in the ground, employing two mirrors on the top of the object glass to reflect the object downwards. The actual lens in use has an aperture of 12 inches and a focal length of 150 feet, while the focal length of the spectroscope is 75 feet. One of the chief peculiarities of the construction was that the girder work of the tower was really in duplicate, one within the other and not touching at any place. While the dome at the top rested on the outer casing, the mirrors and lens were supported by the inner one; thus any wind pressure which might set up vibration in the outer casing did not affect the inner casing, which supported the optical parts of the arrangements.

Reference has previously been made to the various forms of reflecting telescopes, such as the Newtonian, Gregorian, Cassegrainian and Herschelian, and to the first reflector ever made—namely, that by Sir Isaac Newton in 1668.

The growth of this type of telescope will now be briefly described. For a long time the progress was slow, but the impetus was given by Sir William Herschel, who was the first to make mirrors of really large dimensions. The mirrors themselves were composed of speculum metal, an alloy of copper and tin and highly polished. Herschel's largest reflector was 4 feet in diameter with a focal length of 40 feet. It was erected at Slough, near Windsor, in the year 1789. The tube was pivoted near the ground and mounted between high wooden trestles; while there was no restriction to its movement in the vertical direction it was only capable of a very small lateral motion east and west of the meridian.

Just as Galileo with his pigmy refractor revolutionized ideas with his wonderful discoveries, so Herschel with the giant reflector of his own construction made momentous additions to our astronomical knowledge.

Nearly sixty years later (1845) Lord Rosse ground, polished and mounted a 6-feet reflector at Parsontown, in Ireland. This leviathan of 54 feet focal length was mounted somewhat after the fashion of Herschel's, only solid masonry replaced the wooden trestle structure. The movements of the tube were also similarly restricted.

While Lassel's reflectors, the largest of which was 4 feet and made in 1863, were not an advance in size, yet he instituted a great improvement by mounting the instrument equatorially, after the modified "German" type.

Grubb in 1870 completed a mirror of the same dimensions for the Melbourne Observatory, mounting it in the "composite" fashion. This was the last large reflector which employed a mirror of speculum metal, because glass mirrors were beginning to supersede them.

In the years 1856 and 1857 Steinheil and Foucault discovered a method of making mirrors by depositing silver on glass surfaces. This produced a highly efficient reflecting surface and soon came into common use. One of the first large reflectors with this type of mirror was that made by Foucault himself for the Paris Observatory. It was constructed on the Newtonian principle, mounted equatorially on a heavy wooden framework movable on castors and clock-driven.

In 1875 Martin made a 4-feet mirror for the same observatory, but it was only owing to the thinness of the glass disc in relation to its diameter that it was not a success. The completed instrument was mounted in the "composite" form.

An immense advance was made by Common, who in 1888 constructed and used a mirror of 5 feet diameter. The tube was mounted on the modified "German" plan, being placed in a fork bolted to the upper end of the polar axis. To minimize the great weight of the polar axis on its bearings the novel idea of floating it was adopted.

It was not till the year 1908, that is, twenty years later, that a mirror of the same size was made. This was accomplished by Ritchey for the Mount Wilson Observatory: the style of mounting was rather similar to that adopted by Common.

Another ten years saw the completion (1918) of the 6-feet reflector for the Dominion Observatory, Ottawa. This great glass, the work of Brashear, is equal in size to the speculum mirror of Lord Rosse, and weighs 2 tons. The form of mounting the tube is after the "composite" type, the moving parts weighing 35 tons. The telescope is capable of being used either as a "Newtonian" or as a "Cassegrainian."

It should be noted that "rising floors" in an observatory can not be employed for reflecting telescopes of the Newtonian form, because the eye end of the telescope is situated at the upper end of the tube. The staging to accommodate the observer is therefore of very complex construction, and the arrangements adopted vary very considerably from one instrument to another, no two forms being alike.

We come now to the largest reflector of the present time—namely, the Hooker 100-inch erected at the Mount Wilson Observatory in 1919. This mirror of 13 inches thickness, and weighing 4½ tons, has a focal length of 42 feet. While the block of glass was

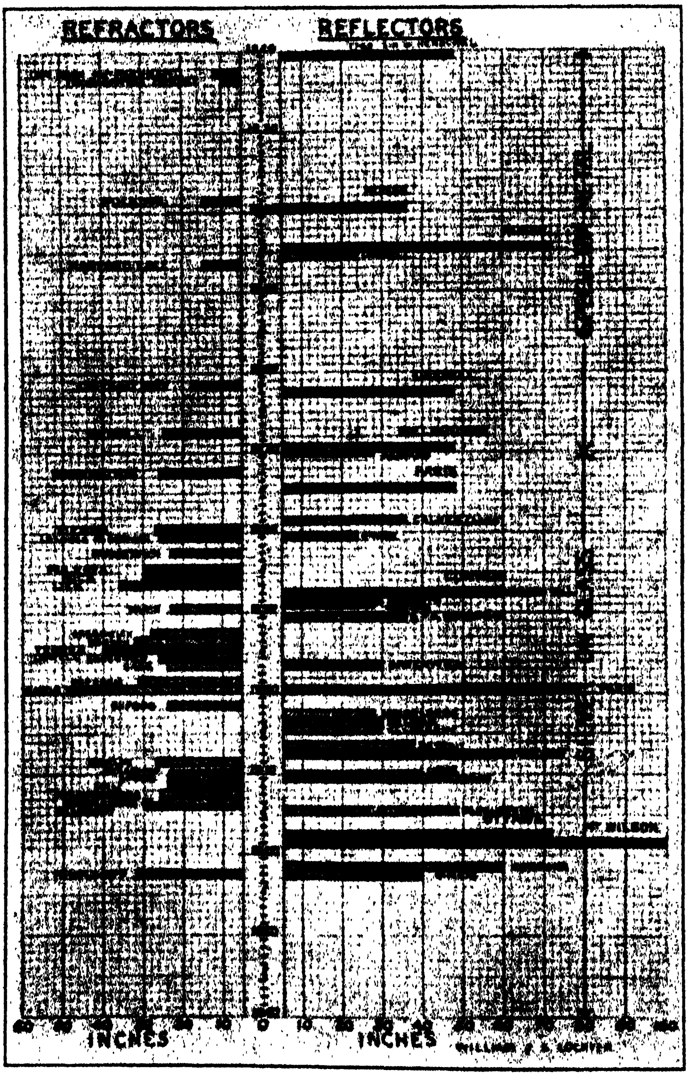


FIG. 3. APERTURES AND DATES OF LARGE TELESCOPES

cast in France, the figuring and silvering is due to the skill of Ritchey. The great tube carrying the mirror is mounted after the "English" type, and the moving parts of the telescope amount in all to 14½ tons. Either the "Newtonian" or "Cassegrainian" form of instrument can be utilized.

Thus, after a lapse of two and a half centuries, the 1-inch reflecting telescope of Sir Isaac Newton has grown into a monster of 100 inches.

Having thus separately surveyed the progress of the growth of

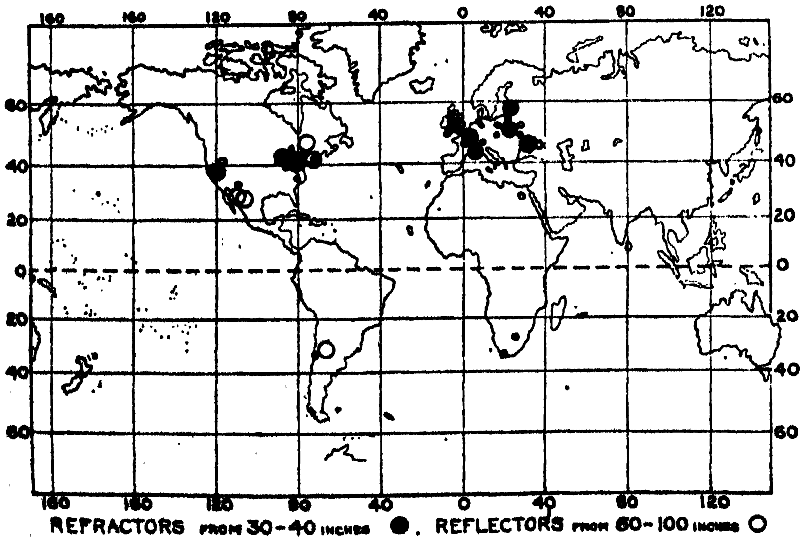
the two types of telescopes, it is interesting to obtain, if possible, simultaneously a bird's-eye view of this progress. This may be possibly accomplished by means of the accompanying diagram (Fig. 3).

The period of time covered is the century beginning in 1820, and while the years are displayed down the center of the diagram, the sizes (in inches) of the object glasses and mirrors are shown respectively on the left and right hand sides against the years of their erection. Many other large instruments of interest, apart from those that were records in size in their time, have been inserted.

No less interesting and important is the study of the geographical distribution of large telescopes. For this purpose the positions of the great telescopes have been indicated on a chart of the World (Fig. 4).

On this diagram refractors from 30 to 40 inches aperture are represented by large black spots, and those between 20 and 29 inches by small black dots. On the other hand, reflectors from 60 to 100 inches in diameter are indicated by large circles, and those from 30 to 59 inches by small circles. It will be seen that the very large telescopes predominate in two main regions—namely, Europe and the United States with Canada. Only one telescope of the very large type is situated in the Southern Hemisphere, and that is the 5-feet reflector for the Argentine National Observatory at Cordoba. This instrument, although completed, has not yet been erected.

South Africa and Australia are both blank in this respect, except that a 26-inch refractor is near completion for the former;



REFRACTORS FROM 30-40 INCHES ●. REFLECTORS FROM 60-100 INCHES O
" " 20-29 " • " " 30-59 " o

Fig. 4. Geographical Distribution of Large Telescopes

but it is hoped that in the near future both these countries will be better represented.

The limit of size of a telescope, whether it be refractor or reflector, for the accomplishment of useful work, has by no means yet been reached, providing the instrument be placed in a specially selected locality high up on some extensive plateau where the "seeing" is of a high-class nature during the greater part of the year.

This limit is at present only temporarily restricted by the maximum limit that can be reached by those whose work it is to cast the necessary glass blocks. The mounting of even the largest telescope is now only a mild engineering problem.

It must not be forgotten, however, that large telescopes are very expensive not only to construct but to house; but experience has shown, at any rate in the United States of America, that when occasion arises there generally looms up above the horizon an enthusiastic private donor.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

THE EVOLUTION OF THE USELESS

"WHAT is the use of it?" was the question that used to be asked by an investigator when he found a strange structure or substance in a plant or animal.

He then set himself to finding out the use of it, and sometimes when he could not find out for sure what it was good for he invented a more or less plausible reason for its existence and peculiarities. It never occurred to him that the reason he had difficulty in getting an answer to this question might be that there was no answer to get. For if the investigator lived several generations back, in the age of the Bridgewater Treatises, he assumed that a living creature was constructed like a machine, where every part has a purpose. If he lived one generation back he assumed that all parts and peculiarities of plant or animal were developed from the accumulation of minute favorable variations and, therefore, were, or at least had been, of value to the creature in his struggle for life. This was the theory of "pure Darwinism," but we must remember that Darwin himself was not a pure Darwinian, just as Karl Marx always refused to be classed as Marxian.

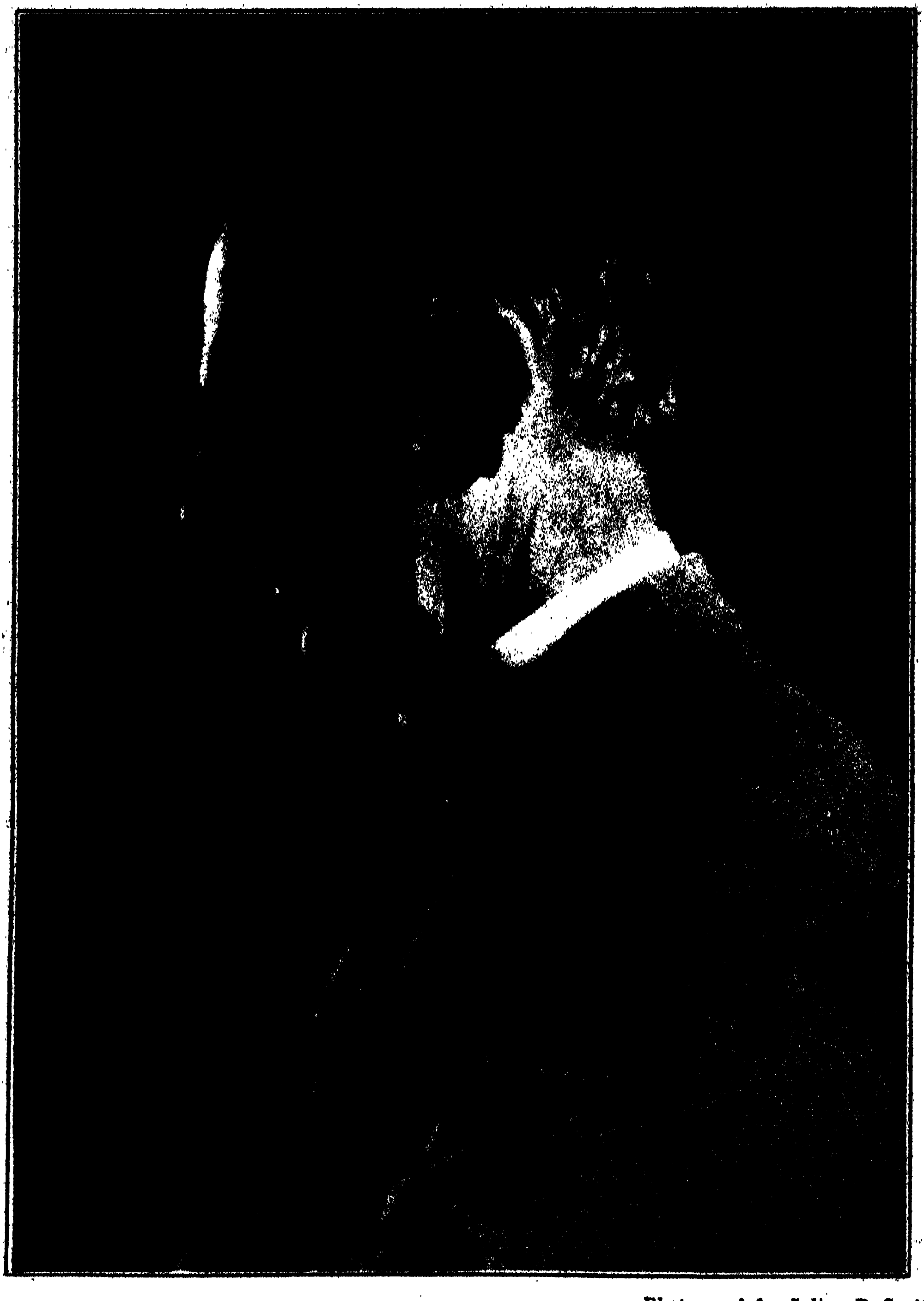
But the biologists of the present generation have given up the expectation of finding a use for everything, for they do not now assume that everything is useful in the sense of being a benefit to the creature possessing it. The characteristic under consideration may be an accidental or inevitable accompaniment of its general development. It may be a mere by-product of its life process.

This modern point of view was expressed by A. G. Tansley, president of the Botanical section of the British Association for the Advancement of Science at the recent Liverpool meeting, when he said:

> An organism may produce parts which are useless or even harmful to it, provided that the whole is still able to carry on and reproduce itself in its actual conditions of life.
>
> In regard to a multitude of characters there is not only no proof but not the smallest reason to suppose that they have now, or ever did have, any survival value at all.

This view will relieve the zoologists and botanists of a lot of the bother they have had in trying to hatch up reasons for everything. Formerly when a plant was found to contain something poisonous or bad tasting, the botanist "explained" it by assuming that the noxious compound was put there or developed there because it kept the plant from being eaten. But the compound is formed by the chemical reactions of the plant's vital processes and it may or may not be a protection to it.

So, too, when the old-school entomologist found an insect that looked hideous—to human eyes—or that gave off an odor that was disagreeable—to human noses—he assumed that the bug appeared or smelled as horrible to the birds that prey on it as it did to him, and, therefore, its enemies avoided it. Perhaps that was so—and perhaps it wasn't. A skunk undoubtedly makes use of its poison gas as a weapon of defense, and it cer-



—*Photograph by Julian P. Scott*

DR. WILLIAM WALLACE CAMPBELL

Recently installed as president of the University of California, since 1901 director of the Lick Observatory.

tainly is an offensive weapon. But many a poor bug may exude an odor quite as bad in proportion to his size and yet not get any benefit from it. Doubtless he has become so used to his odorous aura as to be quite unconscious of it, and often wonders why he is not more popular in society.

A scientist from Mars studying our earthly ant-hill would be quite puzzled to understand why the automobiles shot out jets of ill-smelling smoke until the happy thought occurred to him that it was for the purpose of preventing pedestrians approaching too close and perhaps climbing on behind. He would wonder why heaps of shale were stacked up around our coal mines. But he would consider the question solved when he surmised that they could serve as ramparts in case the mine mouth were attacked by a mob of strikers.

Man may be "the measure of all things," as Protagoras said, but he is liable to mislead himself when he attempts to put his own meaning into nature.

THE TURKEY OR THE EAGLE

Among the problems which the founders of the republic thought they had decided and disposed of, but which persist in bobbing up to perplex later generations, is the question of whether the turkey or the eagle is the more suitable as a national emblem, and hence as the visible representation of a national ideal. The vote of 1782 for the eagle did not settle the matter, and Franklin's plea in favor of the turkey comes up for more careful consideration at Thanksgiving and Christmas time. This patriotic and practical statesman objected to the adoption of the bald eagle as avian emblem of America on the grounds that:

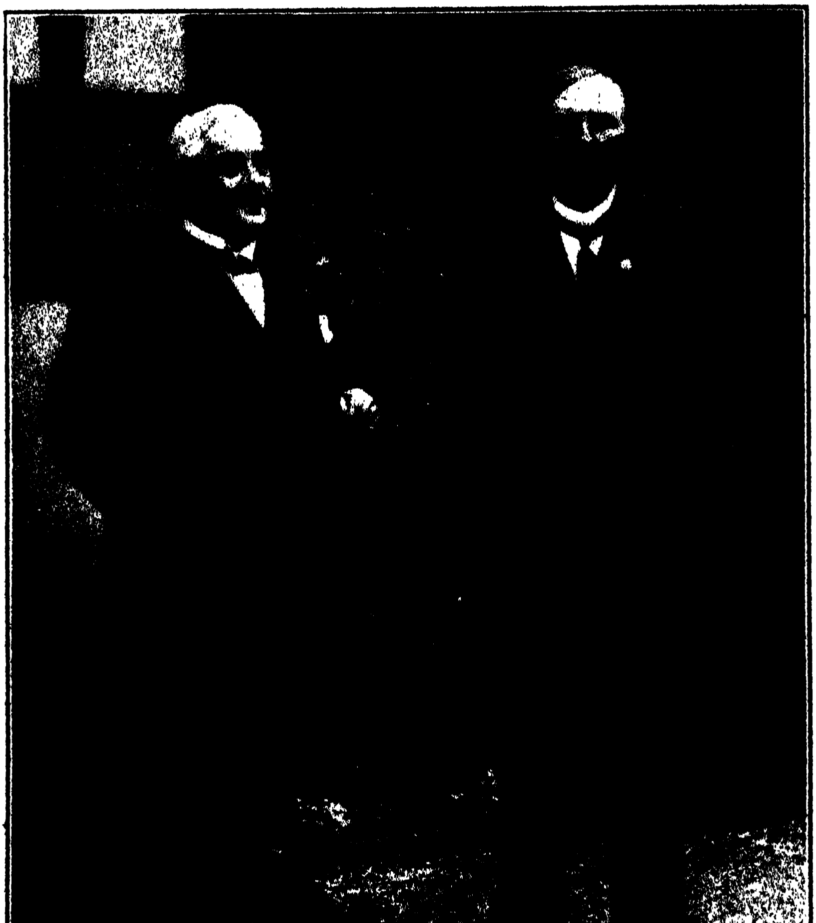
> He is a bird of bad moral character; he does not get his living honestly; you may have seen him perched on some dead tree, where, too lazy to fish for himself, he watches the labor of the fishing-hawk, and when that diligent bird has at length taken a fish and is bearing it to its nest the bald eagle pursues him and takes it from him. Besides, he is a rank coward; the little kingbird attacks him boldly. He is therefore by no means a proper emblem.

Ernest Ingersoll in his new book, "Birds in Legend, Fable and Folklore," says that a mistake was made by the designer of our national coat of arms in taking as his model the bald eagle for "none of these depreciatory things could Franklin have truly said of the skillful, self-supporting and handsome golden eagle—a Bird of Freedom indeed. Audubon named a western variety of it after General Washington. This species was regarded with extreme veneration by the native red men of this country."

The eagle was finally adopted by Congress because they were assured by the heraldry expert consulted that the eagle was "truly imperial" and quite in accord with the escutcheons of the Old World.

This, however, was to Ben Franklin an argument against the eagle rather than for it, and he nominated the turkey as an opposition candidate on the grounds that it was a native American bird, a useful and stately fowl, and not deficient in courage as is shown by the fact that it would not hesitate to attack any "Redcoat" that entered its barnyard.

Whether the turkey would be as readily aroused to the fighting pitch at the sight of modern British khaki or German feldgrau may be doubtful,



—*Wide World Photos*

SIR ERNEST RUTHERFORD AND DR. J. G. ADAMI

Sir Ernest Rutherford (standing on the right), Cavendish professor of experimental physics at the University of Cambridge, presided over the recent Liverpool meeting of the British Association for the Advancement of Science, where this photograph was taken. Dr. Adami, vice-chancellor of the University of Liverpool, was formerly professor of pathology at McGill University.

but nobody who has encountered the turkey on his home ground will question his courage in defending his rights against any invader.

The imperial eagles of Europe, whom our revered forefathers unfortunately followed, have in the last five years lost their heads as swiftly as turkeys at Thanksgiving. The Russian and Austrian, that had two heads, have lost both. Ours is about the only eagle left of the lot, although the Polish eagle has again spread its wings and manifests the old imperial spirit.

In France a similar contest of ideals and emblems is manifest throughout its history. The eagle of Caesar conquered the Gallic cock, but Chanticleer again arose with the First Republic. Napoleon the Great and Napoleon the Little brought back the empire and the eagle, but their reign was short. Just now it seems uncertain toward which ideal France will turn, toward predatory imperialism or utilitarian democracy.

All countries in all times are torn between these opposing forces and are alternately tempted to turn toward the soaring eagle or the farmyard fowl, toward the glory of militarism or a substantial family meal.

The turkey is one hundred per cent. American in spite of its foreign name. The Department of Agriculture should bring suit under the pure food law to prevent such misbranding, for it is a shame that America's only contribution to the domesticated fauna of the world should be credited to the indolent Ottoman.

But we must admit that the turkey is losing repute in his native land. The number of turkeys in the United States is now about 3,000,000. This is more than are in all the rest of the world, but less than there used to be here. Surely the fowl that saved the Pilgrim Fathers when they were in danger of dying for lack of protein is as worthy of honor as the geese that saved Rome.

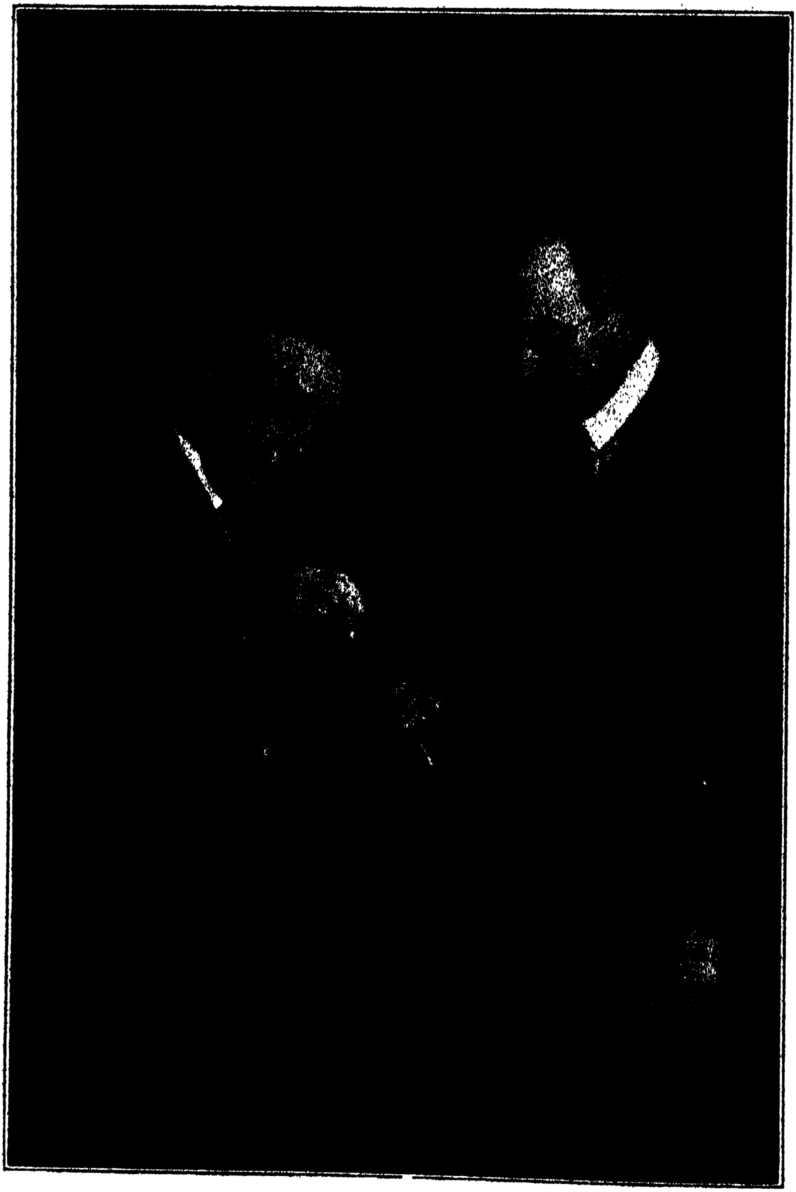
SOY

The recent rise in restaurant prices has sent economical Americans flocking to the chop sueys where a savory and satisfying meal can still be obtained for a small sum. The Chinese in their efforts to keep three million people above the starvation point for three thousand years have been forced to figure closely on food values, and, although they could not tell a calorie from a vitamin at sight, they have worked out some very ingenious dietetic schemes.

Especially have they been successful in getting along with little or no meat and milk. With us Americans meat has been the main part of the meal with vegetables on the side. With the Chinese this is reversed and meat has in many cases been reduced to a condiment. Scraps of beef or pork chopped up in the chop suey or a few shreds of chicken laid on top give the eaters the illusion of a meat dish. And by using sprouted grain they get the vitamins that are absent in our cereals.

The chief difficulty of a vegetarian diet is to get a sufficient amount and variety of proteins. Beans and peas are the richest in proteins, but they are not of the sort and proportion found in meats and needed for our muscle-making.

But there is one exception and that is the soybean. This contains no starch but carries instead from 30 to 45 per cent., of protein, and from 18 to 24 per cent. of oil. From this it will be seen that the soybean resembles



MR. RICE AND DR. CLARKE WITH HENRY'S ELECTRO-MAGNET

E. W. Rice, Jr., honorary chairman of the Board of Directors, General Electric Company, and Dr. John M. Clarke, director of the New York State Museum. Dr. Clarke is holding the little bell which in 1831, during experiments of Joseph Henry, gave forth the first sound ever heard at a distance by the use of the electro-magnet. Mr. Rice is holding the original electro-magnet. On December 17 Mr. Rice and Dr. Clarke made addresses in memory of Henry, which were transmitted by radio from coast to coast and across the Atlantic.

animal foods in being rich in fat and protein and devoid of starch. What is more remarkable, the soybean contains a dozen kinds of protein compounds that are the same as those found in milk. In fact a "vegetable milk" can be made from soybeans and from this vegetable curds and cheese. These form a large part of the diet of Chinese and Japanese who abstain from animal food either because they are Buddhists or because they are poor. By milking the soybean they can get ten times as much lacteal fluid per acre as if they pastured cows on the land. Italian physicians who used soy milk as infant food during the war report that it was better tolerated than cow's milk by some of the babies.

The soy milk products have not yet come into use with us, but the American patron of the chop suey has acquired a taste for another product of the bean, the little glass cruet of brown sauce that seasons the rice. It looks and tastes like meat extract, such as we use in making beef tea, and is really much like it in composition and nutritive value. This shoyu or soy sauce is made by long fermentation and ripening of a mixture of beans and wheat in brine. The longer the process the better the product. Six months or a year may suffice for the masses, but to suit the taste of the Oriental connoisseur it must be sunned for five years or even thirty, the jars being patiently uncovered every day and covered every night or whenever it rains. Over two million barrels of soy sauce are made in Japan every year.

The soybean was first introduced into America in 1804, but it is only within the last ten years that it has come to be commonly raised for oil and cattle food. Now it is becoming one of the major crops in various states. In Ohio at the present rate of increase soy will surpass oats in acreage ten years hence.

But American housewives are slow to admit soy foods to their table in spite of the assurances of C. V. Piper and W. J. Morse, of the Department of Agriculture, that some eighty palatable and nutritious dishes from soup to dessert can be prepared from the bean. It seems that soy will be as long in fighting its way into popular favor as were potatoes and tomatoes in their day.

THE EVAPORATION OF MAN

When Hamlet expressed the despairing desire "that this too, too solid flesh would melt, thaw, and resolve itself into a dew" he did not realize that his wish was being granted even as he spoke. The louder he lamented and the hotter he got about it the more of his flesh was being resolved into a dew which besprinkled his forehead or was thrown off with his breath. Everybody is evaporating in the same way all the time even when he is not conscious of perspiring. In fact, the insensible perspiration accounts for a greater loss of water than what is seen and felt as sweat. All this is necessary to prove this is a sufficiently sensitive balance.

There was such a balance on exhibition at the Carnegie Institution in Washington some time ago. It was so strong that a man could sit in its scale pan and so sensitive that a pin's weight would tip the beam. Dr. F. G. Benedict, of the Nutrition Laboratory, who had charge of the experiment, had to keep putting on weights to make up for what the young man was losing in the way of water vapor while we watched him. Since he had on an overcoat it was evident that most of the water was given off from the lungs and not through the skin. In fact, other experiments have

shown that a man when clothed loses water by evaporation more rapidly than when nude.

Of course exercise of any sort increases the loss of water. Dr. Benedict found that a football player lost 14 pounds of his weight in a game lasting an hour and ten minutes. A marathon runner lost eight and a half pounds in a three-hour race. A varsity oarsman lost five and a half pounds in a four-mile race lasting 22 minutes. Most of this loss is perspired water, largely from the lungs, but a small fraction of it comes from body tissue burned up in the fires of life.

Even when in bed and asleep the loss of water and carbon dioxide goes on continuously. In 158 experiments on 50 different men there was an average loss of one and a third ounces per hour while lying quietly in bed. So the average adult wakes up in the morning after eight hours sleep some ten ounces lighter than when he retired. We restore the loss when we eat and drink.

From these experiments it is evident that scales accurate enough to ascertain the weight of the breath may serve as a measure of metabolism, an index of the activity of the bodily processes, in place of the more bothersome methods now in use, the determination of the heat production by the calorimeter or of the analysis of the expired air by chemical methods. The new method has already been used in hospitals where it is important to know the metabolism of the patient. Six women patients were found to lose from six to thirteen ounces each during eleven hours in bed.

Each breath of air that we inhale adds some oxygen to our bodily substance. But with each breath of air that we exhale the oxygen escapes again, carrying off with it some of the carbon and hydrogen that has served us as fuel. The food we eat keeps up our energy and the water we evaporate relieves us largely of our surplus heat. So the income and outgo of both matter and energy are kept perpetually and automatically in balance. Or if they are not, we become speedily bankrupt and finally defunct. Stopping our outgo of evaporated water would kill us quicker than stopping our income of food and drink.

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THE DAWN OF WESTERN SCIENCE IN JAPAN

By KAN KIKUCHI

[THE following narrative is translated from a novel written by Kan Kikuchi, a well-known contemporary Japanese writer. It was originally published in Kaizo. The author took the material for this part of his story from a book entitled "The Dawn of Dutch Science," which is substantially the autobiography of a physician, named Gempaku Sugita, who lived about 150 years ago.

This narrative should not be regarded as the recital of a mere incident. It has, in fact, a much deeper significance, for it describes how the Japanese were first awakened to the superiority of Western science to the classic Chinese conception of nature. The event may be regarded historically no less important than the visit of Commodore Perry in 1853, because it marks the Japanese introduction to European science.

Only those who know the extent to which Japanese thought in the eighteenth century was dominated by Chinese theories are in a position to realize how much courage and tenacity was needed to make any headway against the prevailing scholastic conservatism.

If I take this opportunity of introducing Gempaku Sugita to American scholars it is because, as guests of that noble institution, the Rockefeller Foundation, we wish to have it known that the earliest and strongest efforts to bestow upon our people the manifold blessings of Western science were made by members of the medical profession.

This historical incident serves to prove that the eagerness for scientific development, which has been so strongly in evidence during the last fifty years, was always latent in the Japanese people, and required only a suitable opportunity to find its practical expression.

For their assistance in the translation I wish to express my indebtedness to Mr. Y. Iwanaga, to Mr. Smith, and to Mr. R. Kumasaki.—MATARO NAGAYO.]

I

It was a little after 10 o'clock when Sugita Gempaku[2] came to the house of Nagasakiya Genyemon, an innkeeper in the Honkokucho Street, Nihonbashi, Yedo. A clerk who was an old acquaintance came out and showed him into the room of Nishi Zenzaburo, the interpreter. It was somewhat of a surprise to find Mayeno Ryotaku[3] already seated there, with an air of serene composure.

Greetings with the host over, Gempaku turned towards Ryotaku and wished him a hearty "Good morning." The latter returned the greeting with a slight bend of a head covered with long glossy hair, without showing even a suspicion of a smile on his pale, pockmarked face with its high Grecian nose. This was nothing new, and yet it was not altogether pleasant to Gempaku.

Ryotaku was a physician attached to the Lord of Nakatsu. He was known for his erudition and scholarship. Gempaku held him in high esteem. In spite of all this, he could not help feeling something that chilled an enthusiastic intimacy.

He had met him several times in this selfsame place. They fell in with each other twice or thrice during the previous year while the Dutch captain was staying here. This Dutch captain had been staying here for seven days, and they had met three or four times in this short interval.

In spite of all this, something interfered with the growth of friendship. Gempaku did not hate him, did not even dislike him, but in his presence he always felt a strange oppression weighing on his mind. "Ryotaku is here," this consciousness was always on his mind; it never left him. Ryotaku's every motion, however slight, fixed his attention. Every smile, every frown, caused him an indefinable sensation. The more he tried to get rid of his irritation, the less he was able so to do.

Ryotaku, on the other hand, did not apparently heed his presence. So at least it seemed to Gempaku, and this embarrassed him all the more.

Everybody came to this inn to meet the Dutch captain, for here in Yedo (the old name for Tokyo) the official regulation regarding the association with the Dutch people was not so severe as in Nagasaki, because the captain's stay in Yedo purported to be only temporary.

Day in and day out there was a large crowd of visitors who were interested in the various branches of the Dutch sciences (med-

[2] 1730–1817.

[3] 1722–1803.

icine, medicinal plants, warenkunde, physics). Among the visitors, there were samurais, merchants and sundry others.

Noro Genjo, Shogun's doctor; Yasutomi Kiseki, medical attendant on the Lord of Yamagata; Nakagawa Jun-an, a physician of the same clan; Aono Chobei, a pawn broker living in Kuramae, who was noted for his inquisitive propensity; Hiraga Gennai, a masterless Samurai who was formerly in the service of the Lord of the Sanuki province; Hosoi Ki-an, a monk in the court service; Okubo Suiko, a scholar of Chinese classics and a few others were the usual habitués.

Questions of every imaginable kind were discussed between these men and the Dutch sailors, through the dubious intermediary of the interpreter. For the most part, the questions asked were foolish and without significance, and did not go much beyond Dutch customs and manners. They would break into laughter when the captain showed them how absolutely stupid their questions were. They would cheer and exhibit childish joy when the captain showed them interesting machines and instruments such as barometers, thermometers, electrometers and so forth.

Ryotaku never failed to preserve his supreme detachment. Never would he ask a stupid question, as the others did. From the beginning to the end, he would remain passive and silent, with a faint smile about his lips, which impressed one as strikingly sardonic. Whoever would laugh over the senseless talk, he would remain indifferent, as if he thought it a matter that little concerned him. His tight-closed lips scarce ever parted.

One thing was singular about this man Ryotaku. He would not omit to put a question or so, when silence born of fatigue reigned over the party. Often his comrades could not even grasp the drift of his question, but, strangely enough, the captain always assumed a very serious air when the interpreter completed the communication, and went into a lengthy explanation with a tremendous enthusiasm on his face. This apparently self-sanctified air of Ryotaku caused Gempaku an unaccountable irritation, though no one else ever seemed to heed it.

It happened one day, by way of an example, that the Dutch captain took out a small sack and showed it to the habitués of the room. The interpreter spoke:

"Captain Karance says he will be ready to give this to anybody who can open it."

Meantime the captain was puckering his face with laughter. There was hearty enjoyment. Hosoi Ki-an took it up, but lost temper, and threw it away when he could not open it.

"I will try it," said Yasutomi Kiseki with an important air. Soon he was at his wit's end and gave it up. The sack travelled

from one person to another. Merriment and jests increased with every failure. This immensely pleased the captain. He was beaming with cynical delight.

Now came Gempaku's turn. He took it up with a happy smile. There was a metal piece about the mouth of the sack which was in all probability the key to the whole contrivance. He tugged at it here and there without being able to loosen it at all. He smiled wryly and was going to hand it to the next one. But there was no one left but Ryotaku, to whom none thought of handing it because he was sitting so sober and grave, looking much too serious for a friendly approach.

"Will you try it, Dr. Ryotaku?" said Gempaku, and started to hand it over to him. But Ryotaku looked at it coldly and did not even deign to try it. Probably he was not quite pleased with the whole party's getting childishly interested in a worthless toy and making such a fuss about it. Or maybe he thought it above high class samurais to let a foreign captain make such fools of them. He did not pay attention to the sack when Gempaku presented it to him, and an awkward silence fell on the company.

Hiraga Gennai, a witty man, came in at the most opportune moment. He looked at the sack, picked it up and opened it without the faintest effort. Astonishment and admiration showed on each face. His sagacity spirited away the chill and brought back joy and laughter.

Something in Gempaku's heart, pride or antipathy or whatever it was, commenced to assume a more definite form from this moment. Gempaku could not ask nearly half so many questions as he wished in Ryotaku's presence. "Ryotaku may know this already"—this thought was constantly haunting him, and he felt as if he had been creating chances to expose his ignorance before Ryotaku. Gempaku had a good amount of hollow vanity to trouble him at heart. He knew how shameful it was to feel so, but in spite of all this consciousness, he could not get rid of it. Thus a very queer, unaccountable psychology prevented him from free questioning, in spite of his burning desire to know more about Dutch civilization and especially about Dutch medical science.

On this very day, he had wished to see the interpreter alone before Ryotaku put in an appearance. He had wished to ascertain from Zenzaburo, the interpreter, whether it was at all possible to learn the Dutch language. So, the next day when he came half an hour earlier and found Ryotaku already there he was quite disconcerted. But he now felt ashamed of himself for worrying so much over Ryotaku. He managed after an effort to dispel his hesitation and disclosed to the interpreter his long-cherished intention to learn Dutch.

"I want you to tell me frankly if it would be possible for me to learn the Dutch language or if it would be a futile attempt giving me only pains for my labor. Tell me frankly for my guidance what you think about it."

Gempaku's inquiry was full of warmth and sincerity. Zenzaburo was very sympathetic, as if he appreciated the inquirer's good intention and honest zeal. But his answer was in the negative. He replied in a very light-hearted manner peculiar to the southerners:

"I have been asked the selfsame question many, many times, but I have always advised people to give up the idea. It is only so much futile effort. Even among my brother interpreters, there are few who have learned to understand written Dutch. The others have managed to put down the spoken Dutch in Japanese characters, learn it by heart and use it as occasion required. For instance, if they wished to ask a Dutch captain or a sailor how to communicate their wish to drink water, they could do it in the beginning only with gestures. Hold your cup in one hand, make as if you poured into it, raise it to your lips and then look inquiringly at them. They will then tell you it is drink. So far, so good, as long as your subject matter is simple enough to admit explanation by gestures. But how could you manage if you wanted to ask the difference between a heavy and a light drinker? You can not possibly do it by a gesture. Suppose you gesticulate like a drinker. The other person will make nothing of it. Further, there are grades and varieties of drinkers. Some drink a good deal without really enjoying it. Others immensely enjoy it but will take little at a time. Such delicate shades of meaning are totally beyond the power of a mere gesture to express."

"True!" Gempaku could not help being convinced, and this made the other the more loquacious.

"Here is one instance which will show how exasperatingly difficult the comprehension of some Dutch words is. They have a word which signifies take a fancy to—aantrekken.

"I have heard this word spoken, and have used it myself ever since my infancy, as my father pursued the same profession. Now I am fifty years old and have come to know its exact meaning for the first time during my recent trip to Yedo."—He was called from Nagasaki to interpret for the Dutch mariners—"'Aan' means the source, while 'trekken' signifies 'to draw.' So both combined come to mean 'attract to self from yonder.' 'Wine Anterecken' is the equivalent for 'wish to drink wine.' 'Home Anterecken' means 'pining for home.' If one single word implies this much you can well imagine the rest. The acquisition, however imperfect, of the whole system is difficult even for those who have kept themselves

in touch with the language from the cradle. For you who stay in Yedo without any chance of coming in contact with Dutch people, such an attempt will be nearly hopeless. Observe what little progress Noro Genjo and Aoki Bunzo have been making for all their splendid efforts along this line. My honest advice is that you give up the idea of such a fruitless task."

Zenzaburo spoke as if he thought the business beyond all hope, even for himself.

"I see your point. Quite convincing indeed!" This was the only answer Gempaku could think of under the circumstances. He could by no means dare to ask further about the best method of study, while the interpreter was so enthusiastically advising him to abandon the idea.

"We will have to give it up. What else can we do when we hear you talk so?"

Ryotaku abruptly interrupted here, for he had up to this moment been attentively listening to the conversation.

"I don't think so. Red-haired people are also human. There could not be any absolute reason why we should not be able to understand books written by fellow-humans. I don't see that this case is much different from that of the Chinese classics which we are now using daily. They were originally imported. The works of Confucius and Mencius, which form the backbone of our moral life, must have been just as difficult in the beginning as the Dutch books we are now talking about. Our ancestors must have taken great pains in elucidating them word by word before they made them their own. How many millions have been indebted to our painstaking ancestors during the 20 long centuries that have since gone by! That is what gives me courage. I am ready for what difficulties may confront us. Try it, my friend! I will go along with you. I am 49 years old and I will strive as long as Providence spares me."

Ryotaku's statement of his firm intention went direct to Gempaku's heart. He felt ashamed before such a noble ideal. Indeed, he could not help taking it as sincere advice to himself. Nonetheless, it was not altogether pleasant to be so abruptly challenged. To be frank, he had been talking like that partly as a friend, in a light-hearted manner. It was taken all too seriously by Ryotaku, who answered him in dead earnest. Gempaku was somewhat disconcerted.

II

It was not full five days after this occurrence that Gempaku got a copy of a Dutch treatise on anatomy.

Gempaku's original aim was information about Dutch medical science. He wished to learn Dutch so that he might thereby be able to understand Dutch medical books. This desire never left him, so when one of the interpreters showed him a copy of the "Tabulae Anatomicae" (Kulm's, 1731), hardly could he suppress an expression of joyful surprise. "Here is the whole secret of the human body," said he to himself when he looked at the minute illustrations of the internal organs in deep red and green. All through the pictures there were innumerable foreign terms. He could not read one of them, but he was burning with curiosity. From the very depth of his heart he felt a consuming thirst for this knowledge. He could not have it for less than three dollars, a sum that made a heavy demand on his poor purse. Without forethought he placed a small silver coin in the hand of the interpreter to close the bargain and left hurriedly for the mansion of his lord master to raise the balance of the fund. He submitted the case to his chief retainer, Oka, who was usually friendly to him, and always turned a friendly ear to his propositions. "If it is a really useful book, our lord will surely help you get it," remarked Oka, on hearing the urgent request of Gempaku.

Gempaku was moved. "I can say nothing very definite now, but you can be sure that I will do what I can to make it useful." He could not help promising this much.

There happened to be a samurai by the name of Ogura Saemon there, who helped the matter along by saying:

"Mr. Oka, pray help him. Dr. Gempaku is not the sort of man who will let your kindness go unappreciated."

III

It was on the third day of March. Gempaku proceeded to the Nagasakiya inn, where the Dutch captain and party were staying. Their interview with the Shogun was over. There was nothing to trouble their minds. They were lounging in idle, comfortable repose. Conversation flowed easily. The captain treated them to a very good wine called "Chinda."

There was quite a number of physicians there, but not Ryotaku. Their conversation was growing enthusiastic. Secretary Babble was a highly trained surgeon. Visitors, seated in a semicircle facing him, assailed him with all sorts of inquiries.

It was getting dark, and the Dutch people left for dinner. The visitors were fatigued and rose to leave. As they were rising, a message on red paper was handed to one of them. It was from the house of Dr. Jun-an, who happened to be one of the visitors.

The red paper was the sign of urgency. As he read it, the gloom

on his face faded and instead there reigned an expression of delight.

"Gentlemen! Rejoice! Our long-cherished desire is now going to be attained. The dissection of a corpse is to take place tomorrow at Kozukappara [Execution ground]."

He showed the note to all. It was an announcement signed by the chief judge from the city court.

"Dissection! Dissection!" everybody shouted. To most of them, the inspection of a dissected body was one of their long-cherished ambitions. This day, this moment, their desire flamed up, fanned by the information about it from Babble, the surgeon. Especially was this the case with Gempaku, whose anticipation was uncontrollable. He had been waiting for this occasion with that impatience which extends from "one day into one thousand revolving years" ever since he secured his "Tabulae Anatomicae" by the help of his clan lord. He noticed all the differences there were between the illustrations in his Tabulae Anatomicae and the traditional theories of the old classic Chinese doctors. Now he could have an object-lesson and compare the truth of the respective statements with the real object.

All faces glowed with joy.

"Let's go home now. We shall get up early to-morrow morning and meet at the rendezvous at Sanya-cho street." So spoke Jun-an to his party, and everybody nodded and agreed. At this moment, there flashed across Gempaku's mind the vision of Ryotaku's face. He knew well enough that Ryotaku was just as desirous to see the post-mortem dissection as everybody else. But the vague antipathy he felt toward him checked his impulse to speak. If Ryotaku were prevented from enjoying this rare opportunity, he said to himself, it would be no more than just retribution for his unfriendly attitude. Neither did he think it his obligation to remind others of Ryotaku when nobody else heeded him. When all rose to leave, he felt his conscience pressing him closer and closer. He was remorseful, for he could not help feeling the baseness of his intention. At last, however, his conscience got the upper hand of his vindictiveness. "We have been forgetting our friend Ryotaku," he said. "Let us take steps to let him know about this." Gempaku felt an immense burden removed from his heart.

"Sure enough, we have entirely left him out," echoed Junteki. "It would not do to ignore him." But there was no very enthusiastic support from the rest.

"It is already past 8 o'clock. It is a long distance to his residence from here. We can not help leaving him out. He may have another chance," said Jun-an, as if excusing himself.

Gempaku thought he might now very well observe silence. He had shown himself dutiful enough to his friend. He felt he was

under no strict obligation or responsibility to help Ryotaku enjoy this chance. But because he was conscious that there was lurking within his heart something that made him glad that Ryotaku would miss this chance, he thought it was not manly to remain silent.

"No, it is not absolutely impossible to let him know it," he said. "At the corner of this street, there is a courier's shelter. Just get one of them to drop a note. We can then accomplish our end quite easily."

It was a splendid idea under the circumstances. Everybody approved. Genteki sat down and wrote the note. Notwithstanding the fact that he proposed the idea himself, Gempaku's mind was not absolutely free of regret for having done so. The anomaly of human psychology! But instantly there came another thought that superseded it. He recalled his recently acquired book, "Tabulae Anatomicae." Something tickled his vanity. What a splendid occasion to show it to Ryotaku and to crush his pride. "However, I have done it, after all," he said.

IV

On the following morning at about half past 4 o'clock, he started from home and came to the rendezvous in Sanya-cho street, just when the boom of the bell of the Sensoji temple was resounding under the purple sky, announcing the advent of the new dawn.

On going into the room of the house, he found Genteki and Ryotaku already there, warming themselves over the brazier. He could not suppress his astonishment at finding Ryotaku already there, for he lived in a place far more remote than his own.

Ryotaku behaved himself with singular courtesy that morning.

"I am deeply indebted to you for the messenger sent me through your friendship," he said. "This rare privilege is solely due to your excellent kindness."

Before this outspoken confession of gratitude, Gempaku could not help feeling ashamed of the ideas he had been entertaining about Ryotaku. "Dr. Ryotaku tells me," Genteki interposed, "he could not sleep a single wink last night. Our messenger came to him at about midnight and he left his house about 2 o'clock in the morning. He says he felt his heart dance within him during the two hours in bed, and could by no means sleep."

This information was disheartening to Gempaku. He found Ryotaku even more enthusiastic than himself. He felt himself inferior to Ryotaku in every respect, and experienced a queer helplessness. But the thought of "Tabulae Anatomicae" instantly dissipated this gloom from his mind. "I am the only one who possesses this rare book," he thought, which was strong enough consolation.

Meantime, Jun-an turned up; half an hour later, Shuntai and Ryoen came in company. Six altogether, they started for Kozukappara.

It was very snappy with the fresh morning breeze of the early spring blowing in their faces. They went on talking gaily. They were all past middle age, but their hearts bounded with hope. Their paces quickened as they walked on. Jun-an, a man of very short stature, was in danger of being left behind. Gempaku thought of disclosing his hidden treasure of "Tabulae Anatomicae." He had already once missed the chance of disclosure at the rendezvous in Sanya-cho street. As they approached the laboratory of Kozukappara, they saw a recently severed head on the exposure stand, the head of an old woman. They immediately decided that it was the body of this head that was to be dissected on this occasion. It was gruesome.

The chief executioner guided the party to the guard room of the officials, which was located at the entrance of the execution place. They had to wait till the preparations were completed.

Gempaku was about to lay his hand on the "Tabulae Anatomicae" in his pocket, as he thought the right moment had come, but simultaneously Ryotaku commenced to undo a package which he had been carrying in his left hand. He did this as if its presence had suddenly flashed on his mind.

"Gentlemen! I have something to show you. I bought this book down in Nagasaki last year. I have been keeping this all to myself ever since. A book on Dutch anatomy, I am sure."

So saying, he took out a book and placed it before his comrades. Genteki took it up, his eyes kindling with curiosity. The attention of all was focused on it. Gempaku, the owner of the same book, could not help doubting his own eyes. It was a copy of the same edition which he had cherished.

He remained aghast for a while. The last chance, on which he had placed so much hope, of taking Ryotaku by surprise faded away instantly. None the less, it was not advisable for him to keep his book concealed any longer.

"Dr. Ryotaku, you have that copy? I bought a similar one quite recently."

He said this with apparent indifference, but felt none of the thrilling joy and cheerfulness that he had expected the day before. It was, in fact, a bitter disappointment.

Ryotaku took up the copy and appeared to be deeply moved. He looked at it from cover to cover, overcome with curiosity.

"Undoubtedly the selfsame book. Strange coincidence, indeed!" he said.

Ryotaku repeatedly clapped his hands. His attitude was as open and frank as the blue of the skies.

"This coincidence is very lucky for the future of Dutch medical science in this country, I should say." He burst into a guffaw. Then he called Gempaku's attention to one of the illustrations inserted in the book.

"Look here, this is the lung, here is the heart, there the stomach, there the spleen.* Nothing could be more unlike the traditional teachings of the Chinese doctors. To-day we shall see from the actual body which teaching is correct."

Ryotaku's face beamed with hope, disclosing his deep interest in the search for truth. His noble enthusiasm extinguished the unworthy sentiment that was troubling Gempaku's mind.

V

The party adjourned to the laboratory.

In one corner there was a shaky shelter with straw mats on the walls. They found a physician waiting for them. There were three professional executioners and two policemen.

As they had thought, the body was that of the female head they saw exposed a while ago, an old woman called "Greentea Hag." She had murdered a number of foster-children. People talked much about her romance in youth, and now even some years over fifty, there were no wrinkles visible anywhere on her body.

The executioner, Toramatsu by name, nearly 70 years old, took up the knife. In spite of his old age he was of sturdy build with ruddy complexion. One received the impression that he got his red face from the countless number of criminals who fell under his sword. He told in a boastful way how he had been accustomed to dissection since his youth.

The corpse was sickening and repulsive, and enthusiastic as they were in the search for truth, they could not resist the temptation to turn their faces away from this headless trunk in front of them. They felt choked by the ugly feeling that entered their systems through their eyes and noses, but they stood it with desperate determination.

The sharp blade of the old executioner, who held it point downward, ripped the chest open. It reminded one of butchery. Hardly half an hour had elapsed since the head had been severed. Blood, still warm and half clotted, came out as the blade plied its way.

The chest was laid open first of all. With all-absorbing zeal, Ryotaku, Gempaku and others engaged in comparing the anatomical illustrations with the corpse, that was being opened, red and crimson, before their eyes.

What wonderful accuracy! Not a single bone, not one line of the weird looking whitish fibrous tissue which runs like a network between layers of flesh, not one lump of yellowish fat, swelling up soft and roundish, but was represented in the illustration. The lungs, the red peach-shaped heart looking up from under the left lung, each was just as it appeared in the picture of the corpse in the "Tabulae Anatomicae." Deep feeling formed a lump in every throat.

Then the abdomen was dissected. The position of the stomach, the bowels folded in an uncanny mysterious form, and then the other various intestines behind the stomach, all were exactly like the picture.

"Wonderful!" shouted Ryotaku, coming out of his trance, and those about him also voiced their astonishment.

On their way home from the execution ground, two fell behind. Ryotaku, Genteki, Jun-an and Gempaku were stirred by the excitement of the demonstration, overwhelmed by the wonderful medical science of Europe. For the first half hour they kept a deep silence, full of emotion. As they passed by the water field of the Asakusa district, Jun-an broke the silence.

"To-day's experiment goes beyond our expectation," said he. "What a shame to have remained ignorant of such facts! Are we not all men who take generous pensions from our lord for medical services? Is it not indeed unpardonable for us to have remained utterly in the dark about the system of human anatomy? However, it is not yet too late if we start now. Let us study every grain of truth about the human body, the foundation of everything else. This is a noble duty that should bind every one who chooses to follow the medical profession."

This did not fail to move everybody to unanimous agreement. Gempaku followed Jun-an's remark by saying:

"You are quite right, and this makes my interest in this book all the stronger. Would that I could translate it! A translation of this single volume will clear away every mystery about the human body, and so will be very useful from the therapeutical standpoint."

To this Ryotaku quite frankly replied: "Yes, indeed! You have my whole-hearted sympathy. I have been anxious to read Dutch books for years. Only I have had no friend to help me, no one to go to. So my days have passed in useless contemplation. Nothing can afford me greater pleasure than to have you for my companion. Fortunately, there remain in me some fragments of the Dutch language, which I started to study during my stay in Nagasaki last year. I will study further in order that we may learn what is in this sealed book. What do you say to starting right away?"

All expressed their approval, clapping their hands. They were all united by a single strong emotion.

"It's never too late to do good! Let us hurry. All of you come to my house from to-morrow on," said Ryotaku, his big round eyes beaming with hope.

VI

According to promise, from the next day on, the four met in Ryotaku's residence in Hirakawa-cho street five or six times a month. The three others could not distinctly make out even the Dutch alphabet. For some time Ryotaku gave them introductory lessons. His stay in Nagasaki had enabled him to read and to understand a little of Dutch grammar. This was, however, nothing very substantial. After a month he found his stock of knowledge exhausted.

Now the four faced the "Tabulae Anatomicae" for the first time. From the very first page they felt as though they were sailing a rudderless boat on the expanse of a broad ocean. They were at a loss as to where to commence.

Near the front of the book there was a picture of a human body lying on its back. They said it would be easier to take up the study of the outside surface of the body because they could compare the Dutch nomenclatures mentioned in the picture with what they actually knew about the human body. The internal organs had better be left for a while, for sheer impossibility of comparison.

This was a fine idea. They took to searching in the pages for the names of the organs illustrated in the picture, and in this way succeeded in learning the names corresponding to the mouth, the brow, the hip, the ear, the abdomen, the legs, the hands, the heel and so forth. But mere knowledge of the vocabulary could avail nought for understanding written sentences. Often they labored in vain over a single clause or phrase throughout a whole spring day. At one time, after two days' hard struggle, they succeeded in making out a sentence which purported to be, "The brow is the hair growing over the eyes." They would break into laughter over such hard-won trifles, but could scarcely suppress the tears of rejoicing.

From the brow downward, they stumbled upon a phrase which states that the nose is a thing that does "Fulhessend." There was no good dictionary available, except the little one which Ryotaku brought back from Nagasaki. "Fulhessend" was explained in it as a swell that will grow on the spot left by the branch sawed off, or a mound the dust makes when a garden is cleaned. This was hardly enough to enable the four to get the idea.

Murmuring the word in their mouths, they thought it out from 10 o'clock in the morning to 4 o'clock in the afternoon. The four looked blankly at each other without exchanging a single word. A little past 4 o'clock, Gempaku jumped up with an expression of joy on his face, slapping his knee with his hand.

"I have it. Just saw off a branch, and the stump will swell up as it heals. The garden rubbish will also form a swell, when you clean it, just as a nose makes a swell in the center of the face. 'Fulhessend' can't be anything else than a nose."

The four clapped their hands with glee. Gempaku's eyes shone with joyful tears. The delight of possessing a world-famed jewel could hardly have surpassed it. Thus it fared with easy simple words, but when it came to a word like "nerve," for instance, a month's time could not work out a solution.

They used to mark a crossed circle on an incomprehensible word and called it a "Gag-cross." Innumerable Gag-crosses were scattered all over the pages throughout the book for the first year. But what could not their intrepidity conquer? Their painstaking efforts were rewarded. Over a year passed, and there was a considerable increase of translated words and as considerable a decrease of "Gag-crossed" words.

The hardships which a pioneer experiences are sufficiently rewarded by the exultation that only a pioneer can appreciate. With the growing understanding of words and sentences, priceless knowledge of truths which were literally a sealed book to their fathers permeated them like the sweet of a cane stalk. The joy of stepping on the fertile land of science unexplored by their predecessors gave them dauntless courage. They used to toss about in bed waiting impatiently for the dawn on the day appointed for a meeting, just like children on the eve of a festival day.

VII

The slight antipathy which Gempaku used to feel against Ryotaku had now vanished without leaving even the shadow of a trace. He had come to hold a very high opinion of Ryotaku's personal character and of his deep interest in science.

As, however, their work progressed, Gempaku came to notice a gradual divergence growing between his ambitions and Ryotaku's. Gempaku aimed at the translation of the "Tabulae Anatomicae." He wished to publish the work at the earliest possible date so that it would advance therapeutics and furnish a stimulus to inventive genius. It must have taken several generations, nay, centuries, of untiring effort before the study of the Chinese classics attained the peak of its development. So must it have been with Dutch

learning. Rather would he concentrate his energy and efforts upon a concrete piece of useful work and complete it in his lifetime than embark on a scheme too stupendous for the lifetime of a single man. It was certainly pleasing to look at the mingling of vari-colored threads, but practically it would be more useful to have one single definite color and discard all the rest. Thus he thought, and had nothing else in his mind but the translation of "Tabulae Anatomicae." The day's portion of his work he never neglected to put down in black and white when he arrived home.

The case was different with Ryotaku. His views and intentions were broad and far-reaching. He aimed at the consummation of the study of the Dutch language. To the solitary "Tabulae Anatomicae" he gave but little attention. The complete mastery of the Dutch language and the ability to read and understand Dutch works in general—this was the goal of his ambition.

For the first year or two there was no open conflict of views between Gempaku and Ryotaku. But as their study progressed they used to dispute once in a while.

"The meaning is clear enough here, let's go ahead." Thus would Gempaku always hurry.

"Don't hurry, take your time. The meaning is clear, but as long as we haven't the grammar, it is little better than mere guess work." Thus would Ryotaku answer quietly.

VIII

Four years passed. Gempaku rewrote the translation twelve different times. There still remained five points they could not make out and seventeen they were not very sure about. Gempaku urged speedy publication, but Ryotaku would not consent to it as long as there remained doubtful or unintelligible points.

They discussed this point several times without being able to reach an agreement; they naturally could not, because divergence came from the fundamental difference of their ideas about Dutch science.

Gempaku at last made up his mind to publish the work, but could not disregard Ryotaku, for it was mainly he who did the translation, though Gempaku took down notes on it. So he called on Ryotaku to write the preface, which the latter refused to do.

"Once, while on a tour in Kyushu, I visited the temple of Temmangu and made a sacred oath that I would study the Dutch language not for fame or profit, but for getting a right key to truth," said Ryotaku. "I prayed for God's protection in this sense and I do not think I should be abiding by it if I wrote a preface as you request. I beg to be excused."

Gempaku could not help feeling depressed, but he could not bring himself to give up his idea. He could understand Ryotaku's attitude, but nevertheless he carried out his determination.

In later years when Dutch learning in Japan had attained considerable headway he recorded his impressions of those earlier days as follows:

"My thoughts were rough and my learning was shallow. I had no ability to make a translation in very comprehensible Japanese, but I had to do it because no one else would undertake it. I had not tried to force the translation of sentences, when I was not quite sure about their meaning, even when I suspected a rather deep implication. I gathered only those portions that I could well understand. I did not take time to particularize fully, for I had to hurry. This was a pioneer attempt, and a pioneer attempt can never be undertaken if one is too nervous about his future reputation. The pith and gist, that was where I had put the greatest stress. Had it not been for Ryotaku, the road could never have been paved. But had it not been also for a man who could neglect minute details for the sake of rough and broad essentials, never could this undertaking have reached such a quick conclusion."

DISTRIBUTION OF STATURE IN THE UNITED STATES

By Dr. CLARK WISSLER

AMERICAN MUSEUM OF NATURAL HISTORY

THE stature of man has always been a matter of interest. Most people prefer to be tall, and everywhere the short have a feeling of inferiority. The small races look upon the tall with envy, and so one may have reason to expect that if the law of selection operates in such affairs, people should grow taller, or at least the tall should segregate from the short. So, in keeping with this popular interest in the subject, stature has received scientific as well as practical attention. Every one in our country is measured many times in his life: the tailor applies the tape to fit clothing; the doctor and the educator test for growth and development and even for mental age by the stature rod; and when one comes to be insured, enlisted or perchance arrested, his stature is again taken. There is thus on file in the many archives of this nation a mass of stature data. The countries of Europe, also, have amassed data of this kind, and, having universal military service, they have in one way and another recorded the statures of their populations by districts. It is plain, therefore, that geographical distributions of stature are available, especially in Italy, France, Germany and Scandinavia. In some cases special surveys of a nation's population have been taken, and several important facts have been revealed in this way. Thus, one finds not a uniform stature throughout a nation, but geographical segregations. Again, the average stature of a nation changes from decade to decade, seemingly increasing, suggesting that mankind as a whole is growing taller.

Somewhat in contrast to the military nations of Europe, the United States has little data of this kind in its national archives; but, on the other hand, there is an abundance of records on file in schools and insurance offices, though not readily accessible. However, the late war, with its universal draft, did give us for the first time a nationwide sample of stature, the data for which were recently published by the surgeon-general's office.[1] In compiling

[1] The Medical Department of the United States Army in the World War, Volume XV, Statistics, Part One, Army Anthropology, Based on Observations made on Draft Recruits, 1917–1918, and on Veterans at Demobilization, 1919. Prepared under the direction of M. W. Ireland by Charles B. Davenport and Albert G. Love.

these data, the several states in the Union were sectioned according to the constituency of population as recorded in the census of 1910, thus dividing the United States into territorial units, each approximately homogeneous in all its parts. Though such a sectioning of the country is somewhat arbitrary, it is, nevertheless, the most satisfactory way of districting for the study of stature, as by this method a district like Detroit is separated out as one unit, while the Ozark Mountain region of Missouri is another, etc. The number of such units in the surgeon-general's list is 156, and the publication referred to above presents the stature for each of these sections. Thus, there are available convenient data for an analytic study of geographical distribution, an aspect of racial anthropometry so far neglected; for, though thousands of measurements have been tabulated and published in technical form, no one has ventured to deal with the subject in a constructive way. Anthropologists, for instance, have shown little aptitude in the use of such data when interpreting population and racial phenomena and, strange to say, have rarely considered the geographical distributions for such well-known characters as stature and breadth of shoulders. So advantage should be taken of the data accumulated during the war to develop a new approach.

If, then, we take a map of the United States and check in the statures for these 156 sections, the geographical distribution for degrees of stature will be revealed. The range of average statures for these sections is from 66.4 to 68.7 inches. Rhode Island has the lowest average, while the highest is found in North Carolina. But, if we treat statures in the usual manner and divide the series of averages for the population sections into quartiles, and plot, we get an interesting result (see maps). The first striking point is that the populations of large cities (marked by circles) are mostly short and that of the sections with similar stature all save two are in northeastern United States. No city is tall and but two, Minneapolis and St. Paul, are above the national average. On the other hand, the tall populations prevail in the mountain districts of the south and in Arkansas, Kansas, Texas and Oklahoma. The other sections for tall stature are chiefly in the west and are sparsely populated. Turning now to the median grade of stature, those just above and below the mean (the shaded areas), we note first that those below the mean tend to cluster around the short in fringes, while those above gravitate toward the tall. The tendency is clearly toward a segregation of the short as opposed to the tall. If now we note the geographical relations only, it appears that in the main tall statures tend to the inland, whereas low statures cling to coastal and other margins of our country.

Of other measurements available we have plotted chest circumference and the index for build, so as to make them comparable to stature. First, as to chest circumference: The largest chests are clearly in the north and west, while the low values cluster on the opposite side of the country. If a line were drawn from Boston to Los Angeles, it would divide the country into two parts, the large chested on the north, the small chested on the south. The cities falling below the line are, with one exception, small chested; yet those above fail to reach the upper group. As in the case of stature, the cities fall in the lower parts of the series for the nation as a whole. There is also a tendency for the smallest chests to be inland with higher values on the margins.

The index of build used in the army tables is found by dividing the weight multiplied by 1000 by the square of the stature. Plotting the values so obtained, we get a striking result, in that the different grades of build are quite clearly segregated. The low values are in the south, the high on the north. The cities tend to be high, the reverse of their relation as determined by stature.

The three foregoing distributions deal with size characters in our population and show clearly that with respect to this character, our population is segregated geographically. The consistency with which all the size measurements for the army fall into this general scheme of geographical segregation indicates that the data are reliable and the nature of the distribution raises a number of important problems. For one, what are the causes that result in such geographical segregation as we have observed and are they peculiar to the United States?

But to deal effectively with our data the respective variabilities must be considered. What variability means as used here is this: If the difference between the tall and the short men for one section is small, we say the variability is low; if great, it is high. Or, when variability is low, every person will be nearer the average size than in a section where the variability is high. This range in size is usually expressed by the mean deviation of individuals from the group average.

Fortunately for us, these deviations have been calculated for the army data and as we are now concerned with geographical distributions only, we may plot these values as before (see maps).

The range of variability for stature, for example, shows a distribution the reverse of that for the average measurement, since the region for low stature is a region of high variability; the same region was, however, distinguished as one of maximum chest size and it is also the place of high variability in chest measurements. Eastern United States, especially the North Atlantic area, is then a region of great range in size. This may mean that among the popu-

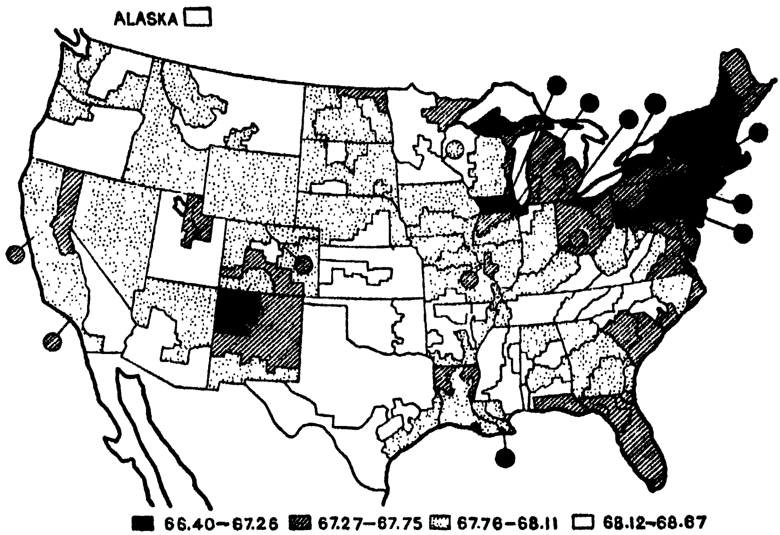


FIG. 1. STATURE

lation of this region will be found some of the tallest men in the whole country and also some of the shortest, but since the average is low, the latter will dominate.

Returning now to distribution, it appears that the phenomenon of variability follows the law of geographical segregation also, but is not directly correlated with size. Again, both averages and variabilities show a tendency to differentiate between inland and marginal distributions. Knowing the history of our population, the interpretation of this is obvious. It means that the older colonists were tall, whereas those arriving recently were short.

DENSITY OF POPULATION AND BODILY SIZE

The sections on our maps vary greatly in density of population, ranging from 0.5 to 16,667 persons per square mile. As every one knows, our cities are the centers of maximum density, but they are also the centers of low stature. To repeat, we found the cities of our country below the average in bodily size, and it is clear that in all cases the city differs from the surrounding districts. Hence, these relations can not be due to accident, for, if chance ruled, one should expect some cities to be populated by very tall people, others by short. Since we find it otherwise, some selective factor must be assumed.

It may be that the phenomenon is entirely a matter of density in population, or, what is more probable, that social conditions draw the short into the cities. The relations here can be made clearer if we consider the calculated variabilities. We note that thirteen cities

have high variabilities in chest circumference and while the case is not so striking for stature, yet no city falls in the class of low variabilities.

Further, if we turn to the actual army tables as published, we fin'' that without exception the inland cities are surrounded by belts of lower variabilities than their own. Thus, the tendency of cities toward high variabilities is indicated. This is also characteristic of cities in Europe and may be taken as a universal law of populations, and, formulated broadly, may be expressed thus: The populations of cities will differ from the surrounding districts in both size and variability.

As confirmation of this we selected the thirteen sections in the United States, characterized as distinctively rural, and also fourteen large urban sections, with the following result:

	St.	Var.	Chest	Var.	Build
Rural Av.	67.87	2.59	34.0	1.95	30.90
Urban Av.	67.10	2.67	33.16	2.07	31.18

So taking the law of differentiation for cities as established, we turn to the question of density, for if this always accompanies these changes, whether conditions are rural or urban, then some causal connection exists. This, also, can be handled empirically.

SECTIONS DRAWN AT RANDOM FROM THOSE WHOSE DENSITY FALLS WITHIN THE LIMITS STATED AND GROUPED ACCORDING TO VARIATIONS FROM THE NATIONAL AVERAGE

	Stature		Var.		Chest Circum.		Var.	
	+	—	+	—	+	—	+	—
9 Sections, density less than 4 per square mile	9	0	1	8	9	0	2	7
9 Sections, from 60 to 80 per square mile	1	8	6	3	2	7	8	1
9 Sections, from 150 to 500 per square mile	0	9	2	7	3	6	8	1

If, for example, we take the density ratings for the sections and sample for high, low and medium densities, the result will be like that in the accompanying table. In this tabulation we have excluded the large cities. What we find is that size both in stature and in chest circumference decreases with density. Variability, on the other hand, tends to increase.

The significance of this is far from obvious, because the districts of median density are not predominantly urban. Still it may, for all that, be a characteristic of the town, or that as the economic and social status approximates that of the city, the population will be affected as stated. As a check upon this we can turn to corresponding data for Sweden and Italy. Thus, the stature for Sweden as a whole is 170.8, and while Stockholm is credited with a stature

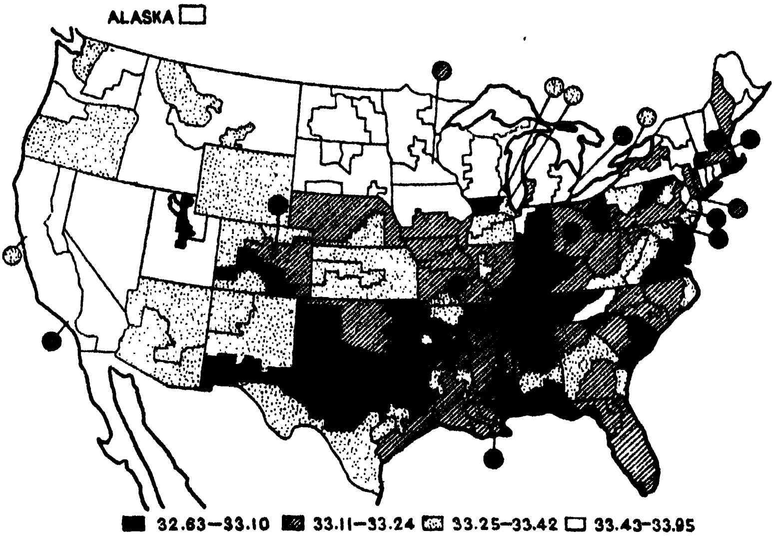


FIG. 2. CHEST CIRCUMFERENCE

of 171.3, the maximum stature for the provinces is 172.9. Yet if we take the provinces with large cities—as Bohuslän, 172.1; Skäne, 170.2; Halland, 170.1; Smäland, 170.5; Ostergotland, 170.4; Uppland, 170.7; Vastermanland, 170.5—it appears that all but one are below the national average.

Turning now to Italy, we find the national stature to be about 164.5, ranging from 161.5 to 167.5. The three large cities are: Milan, 165.7; Naples, 164.2; Rome, 164.2.

Ten other cities above 50,000 in population range from 162.5 to 166.3, and but three are below the average stature. In Italy, then, it is by no means clear that the short congregate in cities, but rather the reverse.

What we observe, then, is that in Sweden the tendency is for stature to fall in the densely populated provinces, but in Italy to rise. This is not so contradictory as it seems, for if we accept the statement that all cities draw foreign stock, it would follow that since the Italians are shorter than most European peoples, the alien elements in their cities would be taller or above the Italian average. On the other hand, the Swedes being a tall people, the tendency of the alien would be to lower the stature. To generalize, then, the cultural conditions in Europe and America are such as to draw into the centers of dense population immigrants from all countries. If the native population of a city is tall, such immigration will lower the average stature; if short, the reverse will follow.

It is, therefore, quite improbable that either city life or mere density of population has any effect upon size, the phenomenon we have noted being entirely a matter of migration.

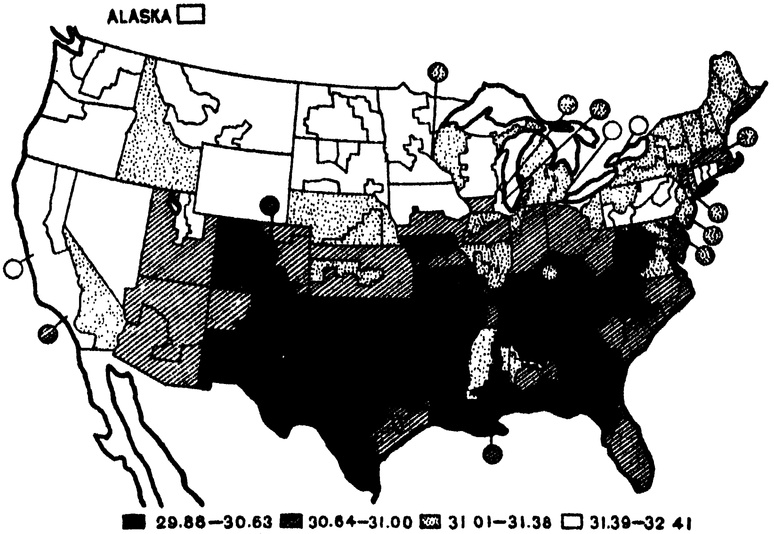


Fig. 3. Index of Build

The Race Factor

While we are now confident that the primary cause for the differences we have observed is racial, we do not know how any given race affects the average national stature. We can, however, approach this problem in our own population by well-known statistical methods. As previously stated, the racial antecedents of the population sections for the United States used in this study are known, so it is possible to single out a given racial strain and determine its correlations. One can, for example, trace the Italians through all the sections and note how their presence correlates with stature. As we know them to be a short people it follows that an increase in their numbers would lower the average stature. Turning to the army tables, we see that 66 sections show an appreciable proportion of Italians, ranging up to 10 per cent. So, by the method of correlation, one can calculate the relation between average statures and the percentage of Italians. The technique of this need not be stated here, for all one needs to know is that if the presence of Italians increases stature, the coefficient of correlation will be +, but if they decrease it, —. What we find when we correlate the percentage of Italians with average stature is a correlation coefficient of — 0.72, which would imply that the presence of Italians is the chief cause of low statures in the United States.

In the accompanying table will be found a number of similar calculations. Degrees of correlation range from 0 to unity and when the number of cases rises to a few thousand, can be expressed accurately to the second decimal; but with so small a series as we

have here, one must allow for considerable inaccuracy in the first decimal.

APPROXIMATE CORRELATIONS BETWEEN THE PERCENTAGES OF FOREIGN STOCK AND BODY MEASUREMENTS

	Stature	Chest
Italians	— 0.72	— 0.47
Scandinavians	+ 0.46	+ 0.31
Negroes	— 0.05	+ 0.06
Foreign born	— 0.42	+ 0.32
Native white	+ 0.85	— 0.23

Yet in spite of the great probable error in these calculations, we have a consistent result; as when the stature increases rapidly with the number of native born whites and declines with the increasing number of foreign born. The latter includes many of the Italians, but not all, those of immediate Italian descent being included in our first correlation. Again, in contrast to the Italians, the presence of Scandinavians increases stature; being a tall race, this is consistent.

When we consider chest dimensions the Italians are again responsible for reduced size, but so are the native whites. The Scandinavians and the foreign born increase chest size. This is again consistent, for the data on chest measurements show high values for the Scandinavians, Germans and Poles, while the native whites, especially the southern mountaineers, are conspicuous for their slim chest.

Turning now to negroes, we find them in the main neutral, since their coefficients are too small to be significant of more than an accidental relation. In other words the negro, who usually lives with native whites, is too near the latter in stature and build to affect the average.

In general, then, by the method of correlation we can analyze a composite population and estimate the influence of different strains upon average size. This method is a promising one, and, if systematically followed, should reveal the part each racial strain now plays in the formation of our population.

THE SIGNIFICANCE OF VARIABILITY

One of the accepted principles of biometrics is that purity of strain determines the degree of variability. Studies of stature, for instance, indicate that the variability from the average will be low when the population is of a single race, but high when a number of races are thrown together. This is obvious, for if Italians and Englishmen are grouped in the same regiment, the range of statures will be greater than for a regiment of Italians only, or again exclusively of English, the reason being that the average stature for Italians is much lower than that for Englishmen. So, in dealing

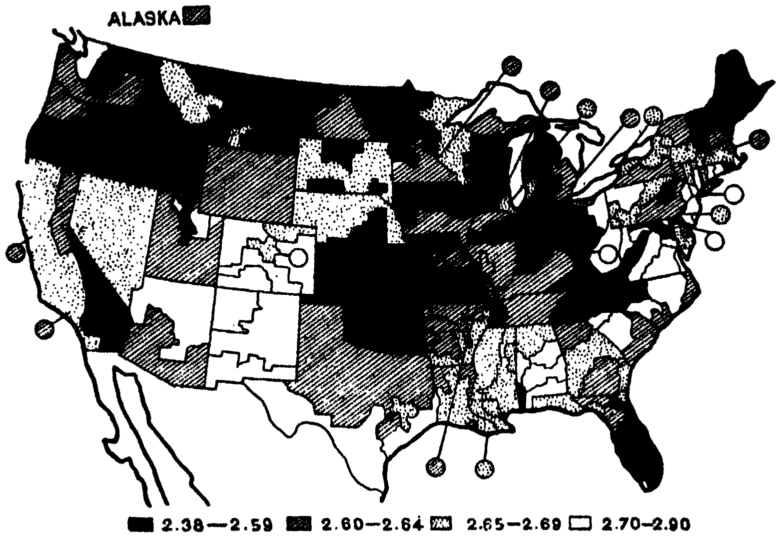


FIG. 4. VARIABILITY IN STATURE

with United States Army data, when we note that the draft quota from a city shows a high variability, we are justified in concluding that several races are represented in its population. Of course, in many instances we can arrive at the same conclusion without measurements, but it is important to once establish the law, since then it can be used to interpret populations for which we have no other data.

However, we have not considered all the possibilities in the case, because geneticists tell us that race-crossing will also increase variability. It is easy to see how such an increase would follow in the early generations, if all characters conform to the Mendelian law, because then both parental types would be represented in the population. If, for example, we assume that tall and short statures, respectively, are unit characters, then the crossing of Italians and English would result in a number of short individuals as well as tall, from which we may infer that the variability for the mixed group will be greater than for the short alone. So on theoretical grounds, at least, the result for cross-breeding need not be very different from mere mechanical mixture, since both give higher variabilities. We see then that while mere measurement will reveal the presence of different racial strains it will not tell us whether the mixture in the population is mechanical or by blood, at least, not until we determine the relation of each to degrees of variability, for no one is prepared to say now if one kind of mixture necessarily gives a greater variability than the other.

Let us, therefore, turn to the first principle formulated above,

viz., that relatively high variabilities indicate the presence of two or more racial stocks. For instance, we have noted that cities seemed to exercise some kind of influence on stature, but found a satisfactory explanation of this in the tendency of different racial stocks to congregate in such cities. Further, it is not quite clear that this will account for all the observed segregation, but certainly for the major portion. As a test, we may check out a few of the largest cities and in contrast a few of the sections rated as highly homogeneous. Reference to the table will show that the latter are by no means alike in their respective racial compositions, but this will make our test all the more satisfactory.

VARIABILITIES FOR SECTIONS KNOWN TO BE HIGHLY HOMOGENEOUS

	Stature	Chest
Negro, Illinois	2.38	1.95
Indian, South Dakota	2.41	1.74
Scandinavian, North Dakota	2.48	1.88
Ozark White, Missouri	2.48	1.76
Mormon White, Utah	2.56	1.88
Russian, Kansas	2.57	1.98
Finnish, Michigan	2.61	1.96
For Large Cities		
Baltimore	2.69	2.08
Boston	2.64	2.14
Cincinnati	2.90	2.09
Chicago	2.67	2.12
New York	2.77	2.15
Philadelphia	2.65	2.02
Seattle	2.70	1.96
St. Louis	2.63	2.07

What the table shows is that the variabilities for the homogeneous sections are uniformly low. In fact, it is here that we find the lowest variabilities recorded for the nation as a whole, the lowest case being that for a section in Illinois populated by negroes. The next lowest is the Indian section for South Dakota, and next in order are the native whites of the Ozarks and the Scandinavian district in North Dakota. It is interesting to note, further, that in Utah, including Salt Lake City, we have a population of low variability, native white and North European descent, but possibly plural marriages have contributed to the result. Turning from stature to chest measurements, we note that the variabilities for chest girth are comparable to those for stature, all the ratings for these sections being near or below the average and so tending to be low. The cities, on the other hand, show high variabilities, as previously noted, and since we know that our large cities contain many racial strains, our test indicates that the law of low variability and racial homogeneity holds. It would follow then that all the black areas on our distribution map for variability of stature are the most homogeneous in population. But this does not mean that all these sec-

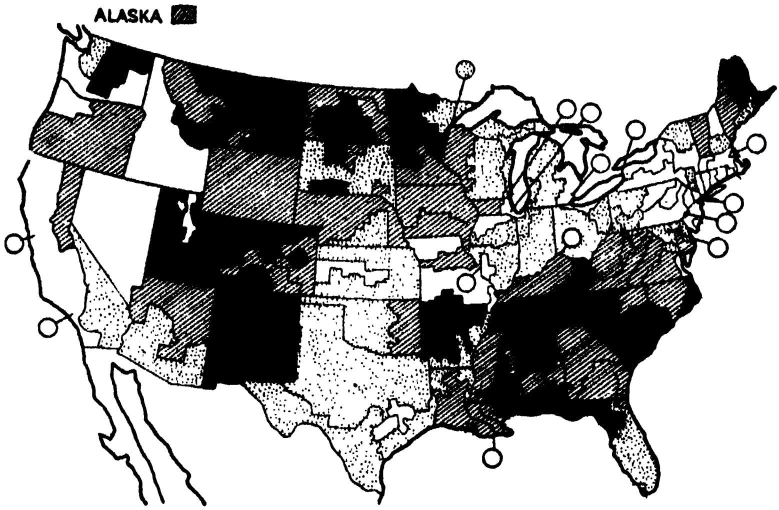


FIG. 5. VARIABILITY IN CHEST CIRCUMFERENCE

tions are of the same stock, for some are Indians, some Scandinavians, etc.

There is, however, still another test we may apply to the case; we can correlate the degrees of variability with racial composition as we did for size. The result is given in the table. From this it appears that the presence of foreign-born and of negroes tends to increase variability in stature, while the presence of native white and of Scandinavians reduces it. Since the native white are North Europeans, as are the Scandinavians, it follows that the increase in Nordics reduces variation in stature, whereas the increase of South Europeans augment it. Chest measurements are in the main consistent with this result:

APPROXIMATE CORRELATIONS BETWEEN THE PERCENTAGE OF FOREIGN STOCK AND VARIABILITY IN BODY MEASUREMENTS

	Var. in Stature	Var. in Chest Circumference
Italians	+ 0.49	+ 0.55
Scandinavians	— 0.64	— 0.83
Negroes	+ 0.14	— 0.23
Foreign born	+ 0.04	+ 0.52
Native white	— 0.30	— 0.45

In a preceding paragraph we noted a progressive change in size and variability with density of population. The sparsely settled districts, for example, tend to low variabilities, except where Indian populations interfere, while the rural districts are intermediate and the cities high. When exceptions are made for the sections of unusual mixtures, this relation holds throughout.

In general, then, we have reasonable proof that the differences in variability for population districts in the United States are for the most part due to multi-racial elements. Cities, in which gather many races, will show the highest variabilities, while districts in which the population tends to be of a single strain will show the lowest variabilities.

Racial Strains and Variability

In the preceding sections we have shown the validity of the assumption that relatively high variability means the presence of two or more racial elements in a population. What we do not know, however, is the degree to which any one race increases the variability for the whole. Thus, in our correlation tables the Italians greatly influence variability, whereas the presence of negroes makes little difference in the measurements considered. Doubtless the answer to this question hinges upon the native variabilities for each racial strain. And most certainly must we turn to this problem when the effects of race-crossing are to be considered. If, then, it is true that the crossing of races increases variability, it should follow that by their respective variabilities the purity of populations can be rated. Such a law is generally accepted in genetics and not infrequently applied to human data. Yet data for a rigid test of the law are not available. All we have are a few trials at Indian crosses, but so far as these go they sustain the assumption. However, the United States army data lend themselves to a comparative treatment of racial variabilities and it is to these that we will turn.

A large number of soldiers were segregated according to racial descent and their variabilities calculated. So from the published reports we have compiled the accompanying table. We note, first, for stature, that the lowest variability is shown by the Italians and the highest by the negro; next to the Italians are the Irish, Hebrews, Poles, all with low variabilities, whereas the English and Germans are rated high. When we turn to weight, the positions of the racial groups remain about the same, the maximum shift being that for the Scotch. This is consistent, since stature and weight are correlated to a high degree and suggest that one must allow for a shift of two to three ranks in our table as accidental variation. Yet the question as to how much allowance we should make for mere accident can be answered by mathematics. Calculating according to the formula for deviations of the variability values in our table, we find that for stature differences of 0.20 and over have great certainty; for weight, differences of 1.50. It would follow, then, that the differences between the Italians, Poles and Hebrews, on the one hand, and the Negroes, English and Germans, on the other, are real differences.

Now, at the outset, we assumed that the less variable the character, the purer the race. If this principle holds, then the Italians and Poles can make the best claim to such distinction. But, if we turn to the column for chest circumference we meet with quite a different line-up, the negroes have shifted from the highest to the lowest rating; the other large shifts are the English, Irish and Hebrews. These shifts are rather surprising, for, interpreted according to the accepted principle, it would follow that as respects chest circumference negroes are the purest race, but in stature the most mixed. In much the same way one could say that the English

Stature

	Aver.	σ
1. Negro	67.70	2.72
2. English	67.75	2.61
3. German	67.73	2.60
4. French	66.37	2.56
5. Scotch	67.93	2.52
6. Irish	67.46	2.48
7. Hebrew	65.71	2.44
8. Polish	66.73	2.41
9. Italian	65.03	2.39

Weight

	Aver.	σ
1. Negro	149.5	17.53
2. Scotch	144.9	17.41
3. English	144.9	17.35
4. Irish	142.9	17.08
5. German	148.2	17.02
6. French	142.1	16.03
7. Hebrew	137.8	16.03
8. Italian	137.9	15.49
9. Polish	145.6	15.29

Chest Circumference

	Aver.	σ
1. Irish	88.67	5.31
2. Scotch	88.57	5.25
3. Hebrew	87.53	5.19
4. German	89.52	5.17
5. Polish	90.42	5.11
6. French	88.49	5.08
7. English	88.18	5.00
8. Italian	88.87	4.94
9. Negro	87.99	4.76

are highly mixed with respect to stature, but pure in chest dimensions. One accustomed to think of race purity as applying to every part of the body equally would at once dismiss this as absurd and reject the whole principle of variability as an index of purity. But the contradiction may not be so absurd as it seems, if one but recall the fundamentals in current views of heredity. What is suggested is that in data of this kind we have an approach to the study of human inheritance, but this is a problem to be discussed later. For the present, then, we shall confine our attention to stature, respecting which the evidence for the validity of the law of variability and race purity promises to be satisfactory.

So, accepting the tentative conclusion that the variability in this character is a true index of racial purity, we may consider the implication of our table with respect to Italian immigrants. Thus, have we reason to believe that the Italians coming here are more homogeneous than the English? But, before going farther, it is well to be reminded that any kind of selection, directly or indirectly correlated with stature, will leave its mark on the variability. We note, for example, that when we segregated soldiers according to race, the variabilities for stature were reduced. Again, we found that population sections composed largely of pioneers presented lower variabilities. So, since we are now dealing with the representatives of each race as selected by immigration, it will not be sufficient to compare national averages.

In case of Italians we know that the greater part have come from southern Italy. From Livi's tables it appears that all southern Italy is characterized by low variabilities in stature, the different provinces ranging approximately from 1.68 to 1.95 inches. So we have:

Italians in U. S. Army	65.03 ± 2.39	inches
Italians for all Italy	64.76 ± 2.06	''
Italians for Southern Italy	64.37 ± 1.95	''

Thus, the Italians in America are clearly more variable than Italians at home. This is an interesting point, which we can not discuss now; but the above shows that the difference between Italians and Englishmen can not be explained away as due to the selection of immigrants according to stature. For, notwithstanding that most of the Italians in the United States come from southern Italy, where the stature is low, the average for the United States Army is still above that for Italy as a whole. Of course, some allowance must be made for military standards, by which a large number of Italians would be excluded. However, this should reduce the variability, and there can be no doubt but that the United States Army variability is too low for Italians in America. The question is, then, can military selection alone account for the position of the Italians in our table? Properly to deal with this problem will require new investigations, but a try-out of the data at hand indicates that it will not, and that in so far as stature is concerned, we must assume positive national differences in variability. The probabilities, therefore, favor the validity of the law for variability as an index of purity, but this discussion shows clearly that it can not be grossly applied and that new researches along this line are highly desirable, for, as a method of studying race-crossing and comparing populations, it is promising.

Conclusion

The foregoing discussion but skims the surface, yet should make clear the richness of the available data as well as the need of ana-

lytic studies on our national population. The results of anthropometric research to date, if properly formulated, will reveal new leads in population problems. In our case we know the history of immigration to our shores, but there are populations in the world concerning which we have little save that derived from measurements. It is, therefore, quite worth while to experiment with these new techniques in the study of our people, where we can check the results. Once having established these methods empirically, one could proceed with non-historical population complexes, like the Polynesians, Indians, Mongols, etc. For example, by a very conservative application of the principles of variability as just outlined, one could sketch out accurately the history of immigration to the United States. With no more before him than adequate measurements of our population, county by county, one would automatically formulate the following:

(1) The greatest amount of racial diversity is in the cities.

(2) The purest communities are in rural districts.

(3) The southern states as a whole have a moderately mixed population.

(4) The regions of least mixture are: *a,* the Canadian border from Maine to the Pacific; *b,* a broad belt running from Ohio and Tennessee to the eastern border of Colorado and New Mexico, and *c,* a belt through the southern states to Texas.

(5) The fact that tall statures are found in the interior of the nation, while the shorter mass on the coasts and the inland borders suggests that the first arrivals were tall, but that these were followed later by a shorter people, and since these mass on the northeast coast, that there was the door through which they came.

Thus it is that anthropometry, when carried out on a large scale, is a most promising method for analyzing populations, even though our observations are limited to stature. Broadly considered, stature is an index of size and a knowledge of variations in size within our population is of both theoretical and practical importance. Clothing manufacturers especially have need of such knowledge in apportioning the sizes of clothing, for the regional variations we have revealed, large peoples in one part of the country, small in others, and the evident drift toward large size among all classes, present them with a perplexing problem. For the sake of this industry alone, a periodical survey of the nation's bodily dimensions is justifiable. But there are other reasons why such a survey should be made at regular intervals. The many and diverse racial elements now in our midst are certain to mix, and the effect of this upon size would soon be revealed by a regional sampling of the population. Such data would be the best approach to the deeper biological questions involved, particularly the specific problem of race mixture.

HALF-BREED

By Dr. ELSIE CLEWS PARSONS
NEW YORK

I

We are sitting in the Chief's small frame house in a half-breed Micmac[1] settlement in Western Nova Scotia. The Chief is an old man, going blind and suffering, too, from erysipelas. This morning he was out when I arrived, but his son and daughter-in-law are there, and presently she has a story to tell me about the girl who married a horned snake. Sahkis, long ago, in a big encampment lived a girl. She was a very proud girl, unwilling to sit where others sat and rejecting all her suitors. An old man told her father that unless he made her marry the youth next to court her misfortune would befall. After that, one day, the girl went to the spring with her birch-bark bucket. She dipped, and as she looked into the water she saw sitting there, cross-legged with folded arms, a beautiful young man. He smiled at her, he stepped out of the water, he carried home for her the bucket of water. "My son-in-law!" said the girl's mother in greeting as he came into the wigwam. In those days that meant marriage. So they married and had a son. "Let us go to my home," he said to his wife, "my parents would like to see my child." Then with child and maternal grandparents they went to the lake into which the spring flowed. At the edge of the lake he said to the old people, "Don't look for us again," and then they saw two large horned snakes and a little snake going into the water.

This widespread Indian tale (I have heard it across the conti-

[1] The Micmacs are an Algonquin tribe of Nova Scotia, Cape Breton and Prince Edward Islands, New Brunswick and Newfoundland. They were among the first Indians of the northeast coast encountered by Europeans; the three Indians taken to England by Sebastian Cabot were probably Micmacs. The tribe became friendly to the French and even after Acadie was ceded to the English in 1713 the Indians remained hostile, until the latter part of the century. They were estimated then and since as between three and four thousand. (Handbook of American Indians, Bureau of American Ethnology.)

To-day the scattered Micmac settlements consist of frame houses in place of the log cabins of half a century ago and of birch covered wigwams. On the annual tribal pilgrimage to Chapel Island wigwams are set up and old ways of life revived. In certain folk-tales and in religion the French influence is still conspicuous although Scotch Catholics say mass and the folk-tales can be told in English. With French and Scotch and English there has been much intermarriage.

nent) was told Mary by her father in Cape Breton. Her father's name was Piel (Pierre) Paul, but he was also known as Moose, because his great-grandfather killed moose easily, with a little knife, which means that he was a shaman with hunting magic.

Mary's story of lure unresisted prompts a story of resistance to lure from Jim, who is splitting maple for baskets, Mary's work, but Mary's hands are stiff from rheumatism and Jim is learning how to make her baskets. Jim's story is a personal experience, with one of the *migumwésu*. "Thirty years ago," he says, "I was eighteen. One day in the woods I saw the shadow of a woman, awful pretty woman. She couldn't speak to me. I couldn't speak to her. After that for two or three years whatever I worked for I got, very easily. If I was fishing, I got lots of fish, plenty animals in my traps. Then I saw her again, in the woods, beckoning to me. If I follow her then, I be following her still. I went to the priest, to cut myself off, not to see her. . . . How's that, Mali?" He is pointing to the pile of maple splints at his feet. "All right, Jim."

In comes the old chief, holding out for us to admire the bunch of fine-toothed leaves and long yellow roots he has succeeded, in spite of his poor eyes, in finding. "That's good for sore eyes," explains Mary. "And it's the best thing, too, for his erysipelas. Since he's given up the doctor's medicine and used that, his leg is a great deal better."—"Golden Thread" in lieu of doctor's medicine, but priestly exorcism and convent-bred Mary and her work in lieu of Migumwésu and the charm that makes work proper to a man so very easy—a medley, indeed, the Half-Breed!

II

As we come down the green trail from Sarusalém into the encampment the people are standing outside their wigwams or are crowding on to the small dock, from which the schooner, which is the lakeway link between Chapel Island and the town of St. Peter's, is about to cast off. All eyes are bent on the boat, and, as we see, when somebody points him out, on a man sitting amidship and with his hands manacled. An unparalleled thing has happened this morning in the Mission camp—a man has tried to kill his wife. First he asked her to go out with him in his row boat to spear eels. She saw his crooked knife at his belt, and she was afraid. When she refused she was bending over their wigwam fire. He kicked her in the face. In the wigwam was one other person, old Stephen Sylliboy, uncle of the Grand Chief. Old man Sylliboy got out as quickly as he could and over to the chapel where most of the people, including the policemen, were holding their morning service. The policemen found the woman on the ground, her face streaming blood. When they handcuffed the man he said he would kill her yet, when he got out.

They had been quarreling for over a year, the story went, "jealousing each other," by which was meant that she was jealous of him, and kept nagging. This from a woman who adds, "But wasn't it good, Mistress, that he had on rubber shoes?" A man who tells me he is the woman's cousin is feeling highly outraged. "That woman, nice woman. Anyhow, man don't need to kick her in the face." "Better keep him in prison for some time," says his own stepfather. "He's all right, except when he drinks. But he wasn't drunk this morning. No whiskey on the Island."

Perhaps he was not drunk, only seeing red, for reasons that were probably not to be referred to in court, and perhaps there was no whiskey on the Island. But the night before, after the Sunday excursionists from Sydney had gone, had I not been offered by my ever hospitable hostess something which tasted more than I supposed possible like the traditional fire-water? "That Mr. McPherson, awful good man, Mr. McPherson, brings us one bottle, every year."

III

My hostess complains a good deal about camping. After her frame house and kitchen range, the wigwam and open fire seem uncomfortable. Next year they will have a canvas tent, she says, and a stove. And there is no water on the Island, the well was destroyed in the French and English War, we have to pay ten cents for a bucket of drinking water. Nor is there any birch-bark on the Island, people have brought bark rolls with them to cover their wigwam poles or, as we did, used tar paper. Hemlock and spruce there are, but Mr. Ahearn, as his wife always calls him, both in reference and address, does not like boughs to sleep on, so we have hay. Mrs. Ahearn is surprised that in my sleeping bag I do not want the cotton sheets she has packed in her trunk.

The trunk has the place of honor in the wigwam, opposite the door, so that when we have visitors of distinction, like the chief from Prince Edward Island or the Grand Chief, blanket and box seat have to be placed for them a little to one side. Otherwise, wigwam etiquette, which is very strict, is well observed. Mrs. Ahearn sits at the right of the entrance, the kitchen, next her, Mr. Ahearn, above her, never below. Between their guest and the fire none of the five children will ever step. Very mannerly, helpful and happy little children, as are Indian children. Only once have I heard any one cry; Eddie did not want to go to school, in the chapel gallery where every morning prayers are taught.

That afternoon Eddie was again saying prayers, as he went on his knees with all the others, perhaps one hundred and fifty, "to see

St. Ann." Men and boys first, after them women and girls, "crawling" inch by inch between Ave Marias, from the ground outside, up the steps, and along the center aisle to where the saintly image rested below the altar, there, still on knees, to kiss the saint's foot and "throw charity" to her, with the right hand; if coins are laid down with the left hand they are "lost to God." This is the time, says Mrs. Ahearn, if anything is the matter with you, and "your heart strong," you are cured, "*sure cured.*" As those devout kneelers moved slowly on, one staid behind, on the porch, a boy of about fourteen. His hands were horribly distorted, and on his neck were sores that sickened. "Rotten since born," says Mrs. Ahearn, "the king's evil, what's that, Mistress?"

Thursday, at latest, I have to leave the Island, a day behind schedule because I want to see what I can of the men's dinner and meeting on Wednesday, and afterwards perhaps, the old-time dance. As yet only "sets" have been danced, to a fiddle, in a packed room in Glebe House, each youth contributing ten cents a set. The Grand Chief has heard indirectly of my intention and wish. He comes in to see us. "What will you throw if I advise my people to dance Indian dance on Wednesday?" he asks, in course of time. "If you leave Thursday and we don't dance Wednesday, perhaps you never see that dance." "Yes, and I would be very sorry for that," say I, "I will throw five dollars." I ask if I may come in to the meeting. I may not, no women are allowed, it would spoil the men. Once a chief's wife went in, and the people did not like it at all. "But I will show you my crown," says the Grand Chief, and he holds out the large gold medal which hangs to the chain around his neck. "That, nice man, Grand Chief, show you his crown," comments Mrs. Ahearn, after he has left. "And ain't you lucky, Mistress, to see Indian dance? Money breaks through everything." "Now, Ina Claire, my dear, you know the Grand Chief was going to have the Indian dance Wednesday anyhow; he told me so himself when I first came. But I'm glad to give the $5.00, anyhow." "Yes, we all feel that way here," rejoins that very resourceful woman. "We throw *everything.* Go 'way, nothing left. Money gone, grub gone, clothes spoiled. . . . We come again, next year, though. . . ."

The men's dinner is eaten at about four o'clock, by the chiefs and captains in the grand wigwam, and, outside, by all the other males, including the little boys. The women have put on their best clothes and sit or stand in front of their wigwams, forming a kind of ladies' gallery. We can hear speeches inside the grand wigwam, and then one by one the captains and the chief from Prince Edward Island come out to be acclaimed by the ring of men seated cross-legged on the ground.

Kwanodek! Kwanodek! sings each as he comes out, a word of forgotten meaning, to a dance step that makes the ladies giggle, except when it is done by the Prince Edward Islander, who stamps with a style we all admire; it is the shame-faced shuffle of our own familiar captains that seems comical. Dance steps alternate with shouts from the sitting men, each of whom is shaken by the hand, "saying bonjours," then, with a final wave of the hat, "wishing good luck to all," captain or chief withdraws into the wigwam. More speeches from within, the chapel bell tolls "the angels," and all go in to the chapel service, this evening to make the stations of the cross, the groups moving in circuit from picture to picture.

Now one more circuit to conclude the movements of the day, in the rutted dance ring between the wigwam of the Grand Chief and the grand wigwam. The dance by the captains was a sometime war medicine dance, before the fray, rendering the dancer impervious to arrow or to shot. This is a war victory dance, for all, men, women, and children. They dance around the circle, one following the other, the step a fast clog, the rhythm given by a man standing at the center beating with a little pine stick upon folds of what should be birch-bark but is brown paper. At the pauses in his song refrain the dancers halt and shout, that is, the six or seven young men and the one old man; the women do not shout, neither the middle-aged woman wearing the long, full skirt called Indian, but once copied, I am guessing, from a French peasant, nor the giggling young girl in high heels and close short skirt, Paris style by way of Sydney. And in silence dances the very little boy, who alone of them all takes an entirely serious view of the performance, stepping not only with spirit but without consciousness of the delighted attention he attracts. With much laughter and shoving others are urged to fall in, but hold back, including Ina Claire, although the Grand Chief himself offers to hold her prayer-book for her.

THE STEINHART AQUARIUM OF THE CALIFORNIA ACADEMY OF SCIENCES[1]

By Director BARTON WARREN EVERMANN
CALIFORNIA ACADEMY OF SCIENCES

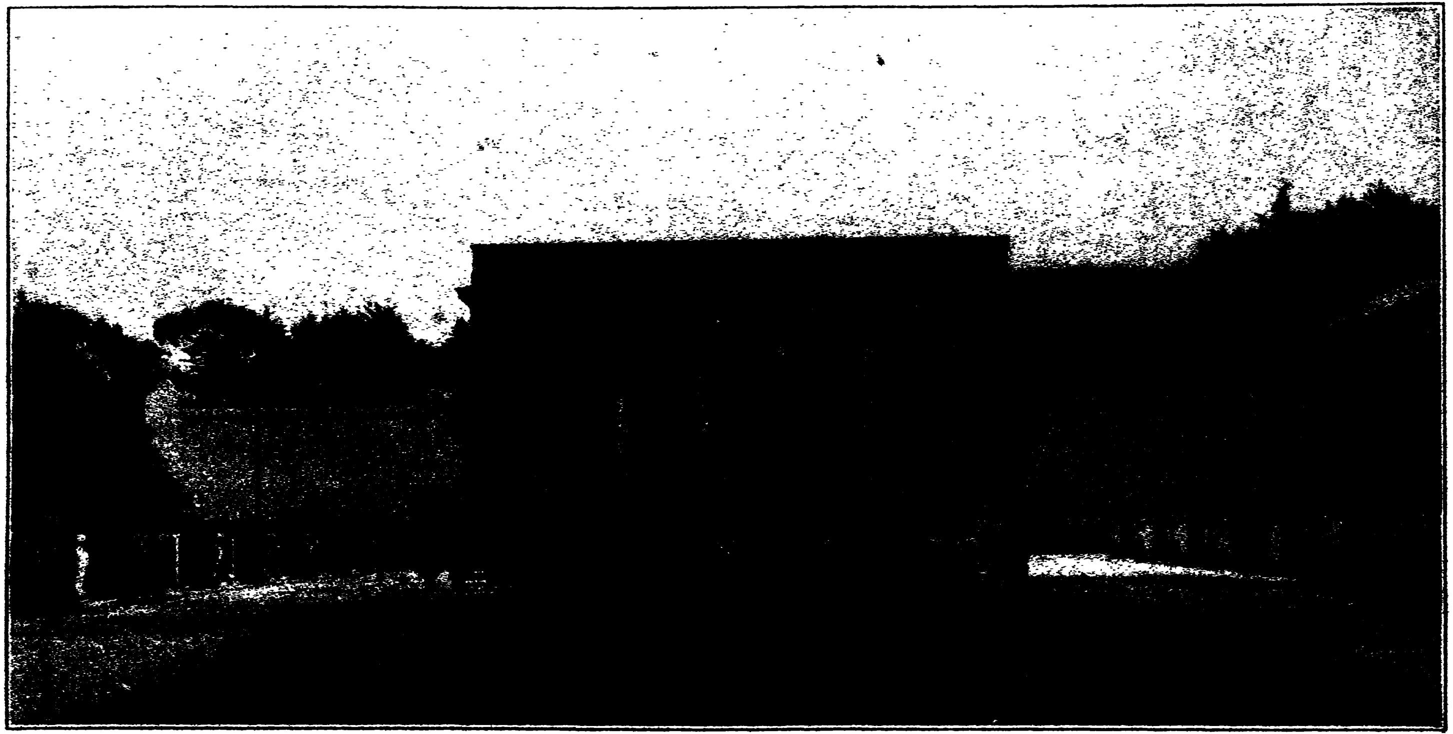
On a sweet day in June, 45 years ago, a young college professor of zoology and a young student of his sat together on the bank of the Cumberland River just below the beautiful Cumberland Falls. The sun shone on the spray, and a rainbow arched the chasm which the river had cut. Beautiful climbing ferns, sensitive briars, orchids and magnolias covered the almost vertical walls that hemmed the river in.

The professor and his pupil saw all these, but they, for the moment, were chiefly interested in a small fish which the student had caught. The professor was giving his student his first lesson in systematic ichthyology. By means of a "Manual of Vertebrates," which the professor had recently written, and which contained descriptions of all the mammals, birds, reptiles and fishes then known from the eastern United States, the little fish was soon identified as the common stone-roller or dough-belly, whose scientific name is *Campostoma anomalum*; "anomalum," because its very long intestine is wound around its air-bladder, like the wire or string around a leaky garden hose to keep it from bursting—a structure quite "anomalous" among fishes.

In the weeks that followed, while tramping southward through Kentucky, Tennessee, North Carolina and Georgia, across the Cumberland Mountains and the Great Smokies, the professor and his student had frequent opportunity to take a look at the fishes in the streams they crossed. They sat on the banks of many of them—as the French Broad, the Swannanoa, the Tallulah and the Tugaloo, and studied and identified such fishes as they had caught. And thus the student's interest in fishes grew day by day.

Since those glorious days, the professor and his student have fished together in many waters, both fresh and salt, and in many lands. They have caught fish, usually while fishing together, in every state and territory in the Union, and in some foreign countries. They, sometimes alone, sometimes with others helping them, have waded a hundred miles or more, in rivers, lakes and along ocean shores, through which they dragged nets with which to catch the fish.

[1] Address given at the dedication and formal opening September 29, 1923.



Steinhart Aquarium

Sometimes the "water was fine" and felt very pleasant; sometimes it was very cold and felt very different; but it was always *wet!* One occasion is recalled when they fished in a certain icy-cold river in Colorado whose name is Rio de las Animas Perdidas, or the River of the Lost Souls.

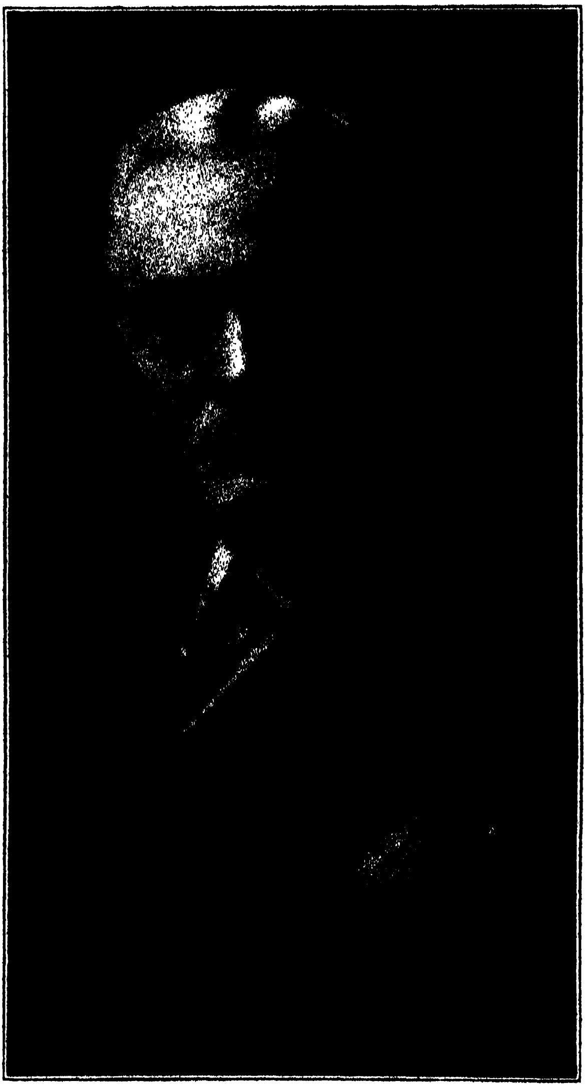
After a hasty inspection the professor decided that the best place to draw the seine was on a gently sloping gravel bar on the opposite side of the river, and said, "We will wade across and try it over there." There was a bridge only a few yards above us, and the three other members of the party said, "Why not cross on the bridge?" But, despite their protest, the professor gathered up one end of the seine, Davis the center, Fesler the other end, the other the collecting bucket, and we all started across, stepping from stone to stone where the water was deep. Soon the professor slipped and went in over his head! Scrambling back to shore as best he could, he remarked, between shivers, "I always thought that the place where lost souls went was a good deal hotter than this place is." We all then went up and crossed on the bridge.

On another occasion we went from Salt Lake City down into the Land of Juab where we fished the Sevier River. The professor had inadvertently left his seining clothes at the hotel, so he said, "You boys can do the seining to-day; I'll stay on the bank and boss the job and examine the catch as you bring it ashore." Fishes of several very interesting kinds proved abundant, and the professor became greatly excited. He disappeared for a moment in the bushes, but soon reappeared garbed only in a hat and a long linen duster, with the remark, "This is great! I want to share the fun with you boys."

We got many kinds of fishes in that interesting stream, and, as we drove back to Juab in the cool of the evening, we commemorated the event by fabricating and singing a "round" (a parody on "The Animal Fair"), which ran something like this:

> We went to the fisheries fair,
> The suckers and chubs were there;
> And old Cottus blob with a red corn cob
> Was combing the bullfrog's hair.
> Pantosteus he got drunk
> And fell on Agosia's trunk,
> Rhinichthys sneezed
> And fell on his knees,
> And that was the end
> Of the Blob,
> blob,
> blob.

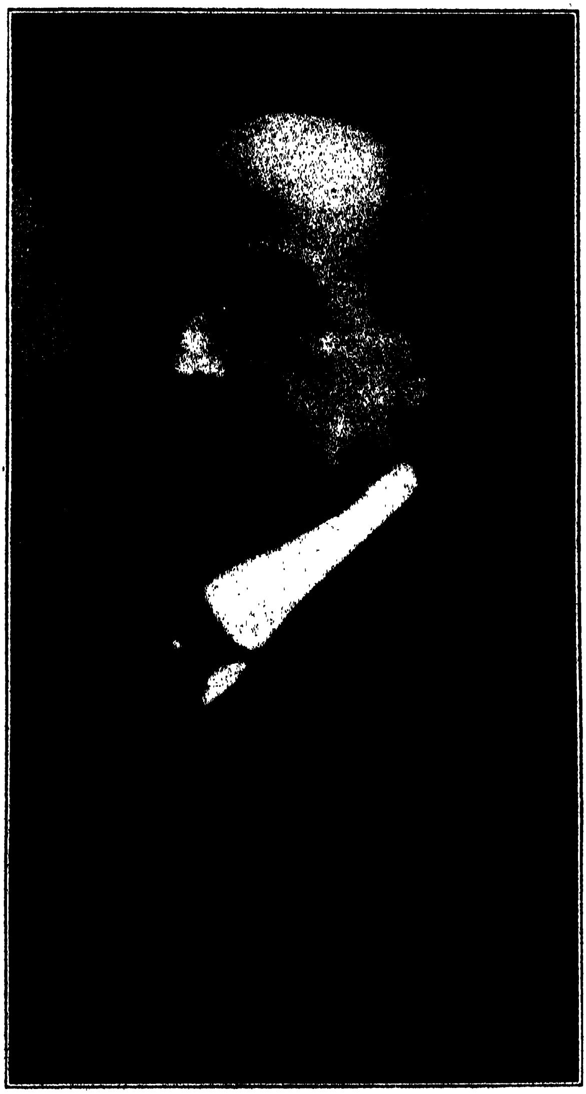
With these many years of intimate association with Dr. David



BARTON WARREN EVERMANN
DIRECTOR OF THE STEINHART AQUARIUM

Starr Jordan in the study of fishes, it was quite natural that I, his student, should develop an interest in live fishes as well as fishes preserved in alcohol. So, in 1916, when some one told me that Mr. Ignatz Steinhart, a public-spirited citizen of San Francisco, was also interested in fishes and aquariums, I determined to meet him.

Through a mutual friend, the late Rudolph J. Taussig, I first met Mr. Steinhart on March 8, 1916. Mr. Steinhart spoke freely



IGNATZ STEINHART
FOUNDER OF THE STEINHART AQUARIUM

of his long interest in public aquariums and the interest of his brother Sigmund Steinhart; how he had dreamed for years of establishing a public aquarium in San Francisco; how he had visited all the aquariums in America and Europe; how he had employed experts to study aquarium problems and assemble data for him; how he had made propositions to various individuals and organizations to join him in the undertaking; how he had met with

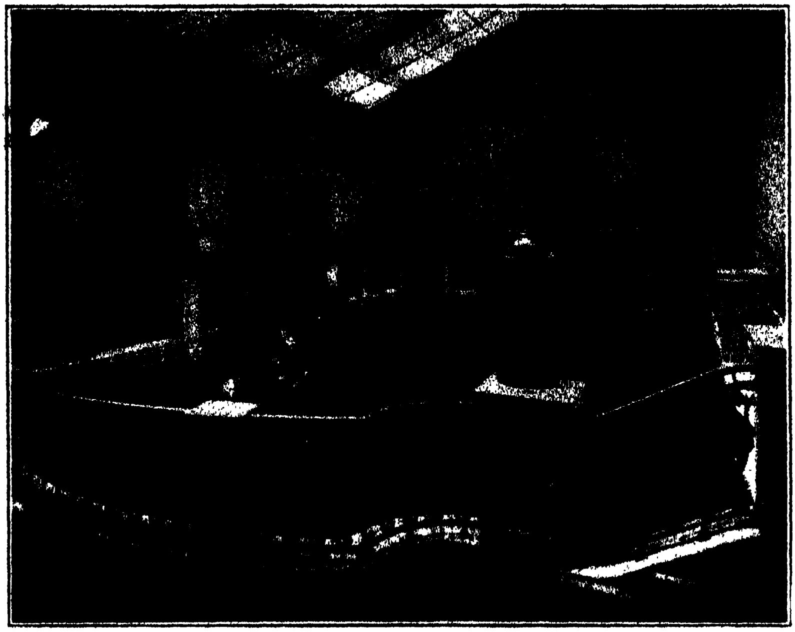
A Portion of the Swamp Room in the Steinhart Aquarium

one difficulty and rebuff after another, until finally he had become so discouraged that he abandoned the idea entirely and decided to devote his money to an entirely different purpose. His decision seemed to be final; and I left Mr. Steinhart that evening with the feeling that there was no hope that he would ever put any money into an aquarium.

Two days later Mr. Steinhart phoned me to come and take luncheon with him at the California Market. I did so and he at once said that he had been thinking about the aquarium matter and wished to ask some questions, particularly as to the amount of money that would be necessary to provide an adequate building adequately equipped, what should be the scope and character of the aquarium, the best location, under what management it should be placed, who should provide the funds for maintenance, and many other details.

Among other things I told him about the great New York Aquarium which was established by the City of New York, the management of which was soon transferred to the New York Zoological Society, a private corporation.

To make a long story short, other conferences followed at brief intervals, and on April 5 Mr. Steinhart told me he had decided to provide an aquarium, provided it could be located in Golden Gate Park and placed under the management of the California Academy



ANOTHER VIEW OF THE SWAMP IN THE STEINHART AQUARIUM
Note the artistic railing around the swamp

of Sciences, which I had assured him was essentially the same sort of an organization as the New York Zoological Society. He stated that he would put $75,000 to $100,000 into it and would leave in his will a similar amount for enlargement.

Among those who had much to do with Mr. Steinhart's reaching this decision was Mr. E. O. McCormick, vice-president of the Southern Pacific. On one occasion Mr. Steinhart and Mr. McCormick visited the park together to consider various sites, and Mr. McCormick then suggested essentially the site which the building now occupies. Mr. Leon Greenebaum, an intimate friend of Mr. Steinhart and an enthusiastic angler, also had much to do in giving Mr. Steinhart counsel and encouragement.

On September 21, at a luncheon at the Palace Hotel at which Mr. McCormick presided, Mr. Steinhart made the first public announcement of his intention to provide the funds for an adequate building adequately equipped, provided (1) that the aquarium be located in Golden Gate Park, (2) that it be under the management of the California Academy of Sciences, and (3) that the city of San Francisco or some other institution supply the funds for maintenance.

From that moment the matter moved rapidly—the adoption of a charter amendment authorizing the board of supervisors to ap-

THE SWAMP ROOM OF THE STEINHART AQUARIUM

It is approximately 58 feet by 60 feet. In the center of the room is a swamp 24 by 40 feet, in which are shown many species of aquatic animals, including alligators, frogs, turtles, salamanders and water snakes; also aquatic plants. Around the swamp are two series of balanced aquariums which are very attractive and interest the public greatly.

propriate funds for the maintenance of an aquarium, Mr. Steinhart's intention to begin construction work early in 1917, his sudden death May 15, 1917, and the announcement that he had left in his will $250,000 to the California Academy of Sciences for an aquarium building and its equipment.

The executors paid the $250,000 to the Academy December 17, 1919. Immediately thereafter the architect's engineer, Mr. Trygve Ronneberg, and I went east and visited all the aquariums in America, and in the summer following I visited that at Honolulu. The knowledge gained from a study of these aquariums was of great value in our planning of the Steinhart aquarium. When the $250,000 was paid to the Academy (December 17, 1919) building conditions were not good, so the trustees loaned the money at a good rate of interest payable monthly. Whenever a monthly interest payment was received government certificates were bought with it. As a result something near $55,000 in interest has now been received, and we have put $305,000 instead of $250,000 into the building and its equipment. Building operations began April 1, 1922, and you now see the building practically completed.

In certain features the Steinhart Aquarium is the most complete and satisfactory of any in this country.

We have four kinds of water—fresh water of the local temperature for local freshwater fishes and similar species; fresh water cooled to meet the needs of trout, salmon and other cold water species; salt water of the local temperature for local and other salt-water species suited to that temperature; and salt water warmed to meet the needs of fishes from the Hawaiian Islands and elsewhere in the tropics.

There will be upwards of 110 tanks, large and small, and large outdoor pools. One unique feature is a large indoor tropical swamp stocked with various species of turtles, frogs, water snakes, salamanders, alligators and aquatic plants. Around the tropical swamp are two series of balanced aquariums which are very beautiful and interesting.

Another unique feature is a fish-hatching equipment where an expert detailed by the State Fish and Game Commission will demonstrate the methods of fish culture. Still another unique feature is a well-equipped biological laboratory in which college professors, high school teachers, students and others can carry on investigations of any problems of aquatic life that can be studied from aquarium material. It is expected that this laboratory will prove of real value to the public schools.

The aquarium employs what is known as the closed circulation system; the water being stored in large reservoirs from which it is

kept circulating through the aquariums, the same water being used over and over again for years.

The object has been to carry out the wishes of Mr. Steinhart by providing an aquarium that will be of the broadest general interest and that will be of the highest educational value to the city and the state. To what extent this aim has been realized you can judge when you enter the aquarium.

The staff has now been selected and the aquarium is in operation. We are fortunate in having secured as superintendent in immediate charge of the aquarium Mr. Alvin Seale, who built the Manila aquarium, which he operated for several years. As principal expert assistants to Superintendent Seale we have secured Mr. H. Walton Clark, for many years connected with the United States Bureau of Fisheries, and Mr. Wallace Adams, as assistant superintendent.

That this occasion is a very happy one for me may well be believed. It marks the realization of an ambition that has possessed my soul for many years. And I can repeat what I have often heard Dr. Jordan repeat from good old Izaak Walton: "It is good luck to any man to be on the good side of the man who knows fish." And I may add, it is good fortune for any man to have "walked with Jordan," and doubly blest is he who has *fished* with Jordan.

And as we are assembled here to-day, my thoughts go back to that delicious day at Cumberland Falls 45 years ago. The wax was soft then and the impress grew indelible. I see again the whole scene—the great silvery waterfall, the broad sheets of white and green water pouring over the precipice to lose themselves in the swish and swirl of the great cauldron at the base; the spray filling the gorge, the spray-washed and diamond-studded ferns and moss and shrubs on the walls, the gorgeous masses of flowers, the mist rising above the gorge and gleaming in the sunlight, and the rainbow arching all.

The professor and his pupil sit together here again to-day. In imagination they have reached the rainbow's end, and they have found, not the mythical pot of gold, but something of vastly greater interest and value to you and me and all the people of California—this beautiful aquarium, this splendid enduring memorial to Ignatz Steinhart, erected, in the felicitous words of the donor, "for the benefit of the inhabitants of San Francisco and others who may enjoy said aquarium and derive knowledge and information therefrom."

Would that Mr. Steinhart could be with us here to-day and enjoy with you and me and all of us, and that all of us might enjoy with him, the fruition of his dream.

ALCOHOL FROM A SCIENTIFIC POINT OF VIEW

III. The Defenses of the Body against Alcohol

By Dr. J. FRANK DANIEL
UNIVERSITY OF CALIFORNIA

Introduction

In a former paper[1] we have referred to the early writings of Arnoldo de Villeneuva (1309) in which he extolled the spirit of wine, attributing to it the prolongation of life. Since the time of Villeneuva mankind has had no little experience with alcohol and should, in a way, be able to offer expert opinion; for the mind of practically every man has been confronted by Villeneuva's conclusion. From a scientific point of view as well as from a general point of view a part of the question, at least, has been answered; that part has to do with alcohol in excess. In excess alcohol is universally held to be injurious. In large doses as we have already seen[2] it is a poison abundantly able to cause death; and in somewhat smaller dosage it may produce chronic alcoholism which may eventually result in the death of the organism.

As for alcohol in moderation some men of to-day accept the dictum of Villeneuva. Others speak more cautiously of "its possible benefit, particularly in advanced life."[3] In order to determine whether alcohol in moderation is or is not beneficial to man it is necessary to look into the general question of the destiny of alcohol in the body. This question may well be divided into two parts. One of these has to do with the action of the alcohol on the body; the other pertains to the defenses of the body against the alcohol. I should like to consider the latter question first, reserving the former for a future discussion.

Defenses of the Body against Alcohol

We have indicated that against excessive doses the body is without sufficient defenses. To review the struggle made in acute alcoholic poisoning or in chronic delirium would be to draw a picture neither pleasant to behold nor profitable for our present consideration. Below the killing or lethal dose, however, the defenses of the body may be studied with profit.

[1] *Pop. Sci. Mo.*, p. 567, June, 1918.
[2] *Pop. Sci. Mo.*, p. 550, Dec., 1918.
[3] Howell: Text-book of Physiology, 1921, p. 929.

Summarily, it is known that when alcohol comes into contact with the mucous lining of the mouth there follows almost instantly a heavy flow of digestive fluids which tend to dilute the alcohol. Again, alcohol is readily absorbed into and greatly diluted by the blood stream. The magnitude of the dilution by the blood is made evident when we find that the alcoholic content of the blood, even in acute intoxication, rarely exceeds one half of one per cent. Further, in the blood stream alcohol is subjected to the most potent of all the defenses of the body, that of oxidation, by which it is destroyed. But, unfortunately, when alcohol gains access to the blood stream it also is on the highway to all the tissues of the body. While some of these are little affected by alcohol, others, like nervous tissue, are susceptible to it even in low concentration.

Secretion as a Defense

Following the ingestion of alcohol two distinct phases of secretion may be noted: First, following a heavy dose mucus may be formed and the actual amount of secretion reduced; secondly, after a moderate dose salivary secretion is increased; in fact, an increase is brought about simply by retaining alcohol in contact with the mucous lining of the mouth. From a moderate dose of alcohol gastric juice may be practically doubled. This increased output of gastric secretion proves to be a defense of considerable importance against the alcohol, but gastric juice thus formed is of inferior quality for digestion. While a normal amount of hydrochloric acid is secreted a deficiency in pepsin, the enzyme of gastric digestion, occurs. It has been found that if 5 to 10 per cent. alcohol be taken the pepsin already formed in the cells is washed out, and further pepsin is not produced in the presence of the alcohol.

While the various kinds of secretions dilute the alcohol to a considerable degree, yet secretions are to be regarded as of relatively minor importance as defense for the body.

Distribution of Alcohol by the Blood

Rate of Absorption from Digestive Tract

To the general question What becomes of alcohol ingested? we may answer that it is readily taken from the digestive tract into the blood stream. Mellanby[4] has shown that usually within an hour after ingestion a maximum concentration of alcohol appears in the blood. That is, if 20, 30, 40 or even 50 cubic centimeters of pure alcohol be diluted to 20 per cent. and given by stomach to a dog the alcoholic content in the blood will reach maximum concentration at about the same time for any of these amounts.

[4] Rept. No. 31, 1919, Med. Research Com., London.

The above statement is true provided the amounts be given at the same percentage, in this case 20 per cent. If given at a lower percentage, for example, 3 per cent., the alcohol will be taken into the blood stream more slowly. This is due principally to the fact that a relatively large volume of water has to be carried in with the lower percentage. As an example, for 30 cc of pure alcohol at 3 per cent. to enter the blood would necessitate the absorption of 1000 cc (nearly a quart) of fluid. On the other hand, for 30 cc at 20 per cent. to enter would involve the absorption of only 150 cubic centimeters.

In certain beverages, however, it appears not to be a matter simply of dilution. For example, English stout is absorbed into the blood at a relatively slow rate, the maximum concentration being reached only after two or three hours. That dilution is not the only factor here involved is made certain by comparing its rate of absorption with that of whisky diluted to the strength of stout. In such a comparison the alcohol of whisky at the same dilution is absorbed more rapidly than that of stout.

Effect of Food on Rate of Absorption

It is common knowledge that alcohol on an empty stomach acts with greater speed and greater violence than it does in a condition of satiety. This difference in action is assumed to mean that it is readily absorbed in the former case, while in the latter it becomes mixed in with the food, and its absorption is delayed until the digesting substances are themselves absorbed.

To test the effects of food on the rate of absorption of alcohol Mellanby gave alcohol with a diet of milk and bread. He found that the rate of appearance of maximum concentration of alcohol in the blood was considerably impeded. Indeed, the retardation in absorption could be produced with milk alone. That this retardation is not due solely to the factor of dilution is shown by the fact that the effect is greater than would be produced by simple dilution of alcohol, and that the effect appears in the blood apparently after fluids have been absorbed. Further than this, he has shown that with separated or skimmed milk little retardation in absorption occurs. The delay is marked, therefore, only in milk which contains butter fat. We assume that this delay is accomplished as in certain other cases in normal nutrition where the passage of fats from the stomach to the intestine for some reason is retarded.

Shall we speak of butter fat and the inhibiting substance noted in stout as defenses of the body? These substances are no part or possession of the body; that is, they are not increased by it, and consequently act to its advantage only in an indirect way.

Effect of Water on Rate of Absorption

If alcohol be taken with water the effects of dilution above discussed appear. If, however, water be given and allowed a sufficient time, two to four hours, to be absorbed before the alcohol is ingested, then the alcohol enters the blood stream at a perceptibly greater rate even than on an empty stomach.

From the above considerations it appears that alcohol of considerable concentration in the digestive tract has its strength greatly decreased by its rapid distribution in a relatively large volume of blood. This is a strong defense for the digestive tract; further, it equalizes the effect on the blood vessels in general. But all that can be said for the defenses of secretion and distribution is that they thin the alcohol out. The total amount of alcohol ingested might remain in the body following these processes were it not for other potent defenses.

Disappearance of Alcohol from the Body

Although alcohol enters the blood stream rapidly it disappears from it relatively slowly. What are the factors involved in its disappearance? What are the defenses employed by the body to this end?

In answer to the question—How does the body rid itself of alcohol?—the early French scientist, Royer-Collar (1839), gave answer through experiment that the body eliminates it through the respiratory tract "unchanged." But Royer-Collar and all other workers who have obtained considerable amounts of alcohol eliminated unchanged were dealing with it in excess. In such overdoses at least two ways of removing the alcohol unchanged are open to the body. A part may be eliminated through the lungs, and a larger part may be removed through the kidneys. It has been estimated that as much as 10 to 12 per cent. of the total amount ingested in excess may thus be eliminated.

How does the Body destroy Alcohol?

It has been known for a long time that alcohol outside of the body will burn, producing a certain number of calories of heat per gram; furthermore, it is known that as byproducts it yields carbon dioxide and water. If we assume that a similar process takes place within the body and that alcohol burns in addition to other foods, we might expect as tests of this internal oxidation (1) a rise of the body temperature, or (2) an increase in the output of carbon dioxide.

We know that one of the first characteristics accompanying the ingestion of alcohol is a "feeling of warmth." This apparent

warmth, however, does not necessarily mean an increase in body temperature; on the contrary, under such a condition the body temperature may suffer severe depression. Indeed, some of the lowest temperatures recorded for the human species were taken at the time of alcoholic delirium of subjects exposed to low surrounding temperatures.

As to the output of carbon dioxide as an indication that the body burns alcohol, we may summarily say that the output of CO_2 upon the ingestion of alcohol is often decreased rather than increased; but this fact alone is by no means conclusive proof that the body can not oxidize alcohol. For as Howell (p. 931) has said, if the alcohol be destroyed in the body in place of an isodynamic amount of sugar or fat a lowering of the output of CO_2 might be expected. This is shown by the fact that if *one* gram of alcohol is burnt it produces 1.91 gr. of CO_2; while 1.7 gr. of sugar (an isodynamic amount) similarly burnt produces 2.77 gr. of CO_2; and .75 gr. of fat (also an isodynamic amount for one gram of alcohol) gives 2.13 gr. of CO_2. This is the same as saying that if the alcohol oxidized contains less carbon than the material which it replaces, that is, carbohydrates or fats, less CO_2 will result. If, on the other hand, the alcohol be burnt in addition to the amount of other material burnt at that time, then more CO_2 would be produced with the alcohol than without it.

Bouchardas and Sandras (1846) were among the first to conclude that alcohol may be actually burnt in the body. Following their experiments came the confirmatory work of Liebig in Germany and of Ducheck in Russia (1853). As a result of the studies of that period scientific men were in agreement that alcohol could be burnt in the body and its energy used as the energy from other foods is used. But how far this is true has been determined only in part even at the present time.

Recent Experiments on Oxidation of Alcohol in the Body

It may be said without reserve that the experiments of Atwater and Benedict[5] constitute one of the most brilliant series of studies yet made on alcohol. These experiments are so far-reaching in importance as to justify more extended consideration at this time.

Atwater and Benedict used a respiration calorimeter which was sufficiently large to house a man in comparative comfort for a period of days and which was sufficiently sensitive to detect and measure the products of oxidation in the respiratory current even in small quantities. To test the accuracy of the calorimeter known quantities of heat were generated electrically inside the chamber.

[5] Memoirs Nat. Acad. Sci., Vol. 8.

The calorimeter was thus shown to register accurately the amount of heat given off. To test it also as a respiration calorimeter a known amount of alcohol was burnt inside the apparatus and the amount of water, carbon dioxide and heat measured. This tested it as a respiratory apparatus and also as a calorimeter.

The first problem tested was how much of the alcohol ingested is burnt. The details of the experiments were somewhat as follows: Men, some unaccustomed to the use of alcohol and others accustomed to it, were subjects of experimentation. One of these, after undergoing a preliminary experiment outside of the calorimeter to become accustomed to a prescribed ration, entered the respiration calorimeter and repeated the diet for a similar number of days. The normal diet consisted of protein, carbohydrate and fat, and to this sometimes was added (or substituted for a part of it) a definite amount of alcohol.

This amount consisted of a daily ration of 72 gr. (2½ oz.) of absolute alcohol divided into six doses. Three of these doses were taken at meal time, two between meals and one upon retiring. The doses not taken with meals were immediately followed by 200 cc of water. The amount of alcohol taken per day, as the authors suggested, was about equal to that in a single bottle of claret similarly taken in six doses. The immediate effect of such a dose was so slight as practically not to affect the nervous system. This was made evident by the fact that only one of the men studied experienced any effect and that was only a slight ringing in the ears.

Proof that Alcohol is Burnt in the Body

Perhaps it should be further emphasized that the dose of alcohol studied was small (less than one half ounce at a dose). The purpose of so small a dose obviously was to prevent its secondary action as a drug. The amount which was oxidized was taken to be the difference between the amount ingested and that given off unchanged. Amounts of alcohol in the exhaled air and in the urine were determined, and only 2 per cent. of the total amount taken was eliminated. In other words in small quantities 98 per cent. of the alcohol ingested was burnt. This was especially interesting when 5 per cent. of fats and 7 per cent. of the proteins were eliminated unoxidized.

Recently Mellanby[6] has conducted a series of experiments which add to our knowledge of the oxidation of larger doses of alcohol. In this series it was found that after alcohol has reached its maximum concentration it disappears from the blood with great regularity but at a remarkably slow rate. In a dog of 13.5 kilograms weight it took 20 hours for 50 cc of alcohol to leave the blood; that

[6] *Loc. cit.*

is, about 2½ cc were burnt per hour, giving a rate of oxidation of 0.185 cc per kilogram per hour.

In the experiments of Mellanby the maximum concentration mounts considerably above 354 cmm, which is at the threshold of intoxication. Despite this fact, the plane of oxidation is relatively regular.

From experiments like the above we may confidently conclude that the body is able to oxidize alcohol. A further question is: Can the body use the energy of oxidation? If so, in what way can it use it?

Substitution of Alcohol for Food Substances

Hammond early observed (1856) that users of alcoholic drinks often gain in body weight. His interpretation of the phenomenon was that alcohol retards metamorphosis of old tissue, promoting the formation of new, and limiting the consumption of fat. That the body may use and, as a consequence, limit the consumption of fat is, as we shall see later, shown by experiment; but that alcohol which possesses no nitrogen can not enter into the formation of new tissue is equally well established. In general, then, the phenomenon of increase in body weight was early interpreted to mean that the tissues of the body in some way protected themselves at the expense of the alcohol. Alcohol hence became spoken of as a preventer of waste or a conserver of tissues. Now it is quite certain that if alcohol conserve the tissues, preventing their consumption, this might be done in one of two ways: First, the alcohol might act as a drug to prevent the tissues from being used up; or secondly, it might prevent the destruction of the tissues by being used in their place. It is evident that whether it act in the one way or in the other the same outward result would follow, that is, the body would gain in corpulence.

Atwater and Benedict sought to find out in how far the body can utilize alcohol as a substitute for other food substances. That is, to what extent can alcohol be used in the place of the fat, thus allowing the fat to be stored up or "spared"? To test this question a diet of protein, fat and carbohydrate was given to which was added an amount of alcohol. As a result of this ration less carbon was eliminated from the body, showing that fats or carbohydrates or both had in some way been spared combustion. Following this experiment alcohol was substituted in the following way for an isodynamic amount of fat or of carbohydrate. A given diet was selected in which the actual heat value of the food, if the food had been burnt outside of the body, was known to be 2,500 calories. Now 500 calories in potential alcohol was substituted in place, say, of an isodynamic amount of fat or of carbohydrate. In all such cases the normal heat output for the expected amount (2,500 calo-

ries) was realized, showing that the alcohol had been converted into energy in place of the substances for which it had been substituted. From this series of experiments it is shown that alcohol may be substituted for food substances, thus sparing these substances and allowing them to be stored.

Energy from Alcohol used in Work

While the experiments of Atwater and Benedict were planned primarily to test whether or not the body can convert alcohol into heat, the experiments give suggestive data on the production of muscular activity when alcohol is the source of the energy. In the series to test the utilization of the energy of the alcohol in work two types of experiments were made. One of these was the so-called rest experiment. In the other experiment hard muscular work was done. As to the rest experiment it is of course known that a great amount of internal work, as, for example, heart beat, respiration and the like is constantly being done by the body. The work experiments were in general similar to the rest experiments, excepting that the subject put in eight hours a day on a stationary bicycle. This bicycle was attached to a dynamo so that the work done could be measured in terms of heat produced. The heat resulting as muscular work on the pedals was converted into electrical energy which was led through an electric lamp and measured in heat units. In addition there was produced frictional heat. We may first give the plan of an experiment in the production of heat energy comparing an alcoholic and a non-alcoholic diet, giving at first the so-called rest experiments. The average of thirteen such experiments follows:

Rest experiments	Energy in calories of food taken per day	Energy in calories reclaimed per day
Without alcohol	2718	2723
With alcohol	2746	2752

The intake in each case was practically equal to the output, and the alcohol was apparently used as well as the other foods in producing energy. The energy which was latent or potent in the alcohol was wholly transformed in the body, it was actually given off from the body, and further it was actually recovered as heat.

In the work experiments almost a thousand calories more were needed than in the rest experiments. But of these 500 calories in alcohol were substituted. That the alcohol was burnt to form the energy is indicated by the following experiments:

Work experiments	Energy in calories of food taken per day	Energy in calories reclaimed per day
Without alcohol	3668	3671
With alcohol	3698	3676

In the rest experiments above, almost one fifth of the energy (heat) formed came from the alcohol (total energy of daily diet 2,700 calories; 512 calories, energy in alcohol); while in the work experiments at least one seventh to one eighth resulted from the burning of the alcohol (total food value, about 3,700 calories; 512 calories in alcohol).

These experiments demonstrate that the body in health can by oxidation convert alcohol into energy, that it is capable of substituting a small amount of alcohol for other food ingredients; further, the experiments strongly indicate that the energy formed from small amounts of alcohol can be used in work. But it should be emphasized that further than this Atwater and Benedict do not go. They say:[7]

> It should not be forgotten that the desirability of alcohol as part of a diet for muscular work is not decided by the narrower questions here discussed. There is a very decided difference between the transformation of the potential energy of alcohol into the mechanical energy of muscular work and the advantage or disadvantage of alcohol in the diet of people engaged in muscular labor. Even in the small doses in these experiments there were indications that the subjects worked to slightly better advantage with the ordinary rations than with the alcohol. The results of practical tests on a large scale elsewhere coincide with those of general observation in implying that the use of any considerable quantity of alcoholic beverages as part of the diet for muscular labor is generally of doubtful value and often positively injurious. Aside from the question of the power of alcohol to protect protein and fat and supply energy to the body for various useful purposes there are the far weightier considerations of the general effect of alcohol upon the muscular and especially upon the nervous system, and upon health and welfare. Upon these serious hygienic, economical and ethical problems the experiments here recorded throw no special light.

Perhaps we are now in a position to inquire more specifically: Can the body use the energy of alcohol as it would utilize the energy derived from the oxidation of foods in general?

We recognize two services performed by foods: (1) They may build up living protoplasm, and (2) they supply energy. Certain foods, the proteins, can build up protoplasm and can produce energy which may either be stored for future use or used immediately; other foods, the carbohydrates and fats, while unable to repair protoplasm, can produce energy to be stored for the future or to be made immediate use of. Alcohol can not repair protoplasm; neither can it produce energy to be stored for future use. Its use as a food is restricted to the production of energy, which may be made immediate use of. Further, it should be noted that its employment as a fuel to be made immediate use of is conditioned by the amount which can be used without disturbing the nervous balance. Beyond this amount alcohol acts as a drug and as such can not be said to have the same valid nutritive qualities.

[7] Memoirs, Nat. Acad. Sci., Vol. 8, p. 284.

GEOLOGY AND OUR CIVILIZATION

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At this time, when all things in life are being scrutinized and even values are undergoing revaluation, when new standards are being set and some old ones discarded, when some gods whom we formerly worshipped are found to have cloven feet, and disillusionment makes many people doubt all things, when new definitions of culture and education are being given, the writer has thought it might be of no little interest and perhaps of value to present the brief for his chosen profession—not that its claims to recognition particularly need a champion, certainly not in the commercial field, but rather because its place in the general scheme of a higher culture is not as clear to the layman as it is to those who know the profession.

And right here the temptation can not be resisted to launch one Parthian arrow about this matter of culture. Many people are under the delusion that culture consists in the quoting of fine phrases, particularly in a foreign language. Culture is not restricted to the field of the humanities. Real culture consists in a liberal education (which of course, must not leave out the humanities) and gentleness of spirit, as Galsworthy puts it. This last is of far greater importance than either the classics or science, the late demented Nietzsche notwithstanding.

In these latter days some of the superficially minded are sending up a smoke screen (principally to hide their own shortcomings) at all things classical, and it has become the fashion to speak of geology as "earth science." Why do they object to the term geology and still use geography? And so, for the sake of those who have been led astray and have deliberately cut themselves off from partaking of the world of thought represented by the classical school, who find Latin and Greek merely encumbrances, forgetting their really great "practical" worth, we shall say that this discourse deals with earth science, or, rather, some phases of it. All science, for that matter, is earth science, even though it attempt to explain the Milky Way.

Man's dwelling-place, as far as we know, has always been the earth, and for eons to come may continue to be, and yet how few people know anything about our habitation! It is a trite saying that we all come out of the soil and in a brief time go back to it. This was the song of the Psalmist of old, of Omar and of preachers

throughout the ages. Before the coming of the balloon and the airplane the farthest any one by his own efforts could get away from earth was about six feet. And still on we go, generations and generations, not knowing our own dwelling-place, whence we came, whither we go or why. Most of us are simply "on our way."

> Into this Universe, and Why not knowing
> Nor whence, like Water willy-nilly flowing
> And out of it, as Wind along the Waste,
> I know not whither, willy-nilly blowing.
>
> A moment's Halt, a momentary taste
> Of Being from the Well amid the Waste
> And lo!—the phantom Caravan has reached
> The Nothing it set out from—Oh, make haste!

How utterly false this philosophy is we hope to show in later pages. The Rubaiyat is a beautifully sounding poem, but poor philosophy. It speaks to the flesh, not to the soul.

The perverseness of man in persisting in living on the slopes of volcanoes, on hurricane-swept coasts, or over dangerous fault cracks has always been a mystery to the writer, but still man does it and disasters come and come again in spite of prayers and signs made across the breast. With all the Sodoms and Gomorrahs, Pompeiis, Messinas and Galvestons, the average man *will* not learn from his experience.

The struggle of life among many people still goes on much as does a complicated game essayed by beginners who have not even taken the trouble to learn the rules of play. This thought has been so well put by the great champion of Darwin in his essay on "What is a Liberal Education?" that we are loath to pass on without quoting a few lines:

> And by way of beginning, let us ask ourselves, What is education? Above all things, What is our ideal of a thoroughly liberal education?—of that education which, if we could begin life again, we would give ourselves—of that education which, if we could mould the fates to our own will, we would give our children? Well, I know not what may be your conceptions upon this matter, but I will tell you mine, and I hope I shall find that our views are not very discrepant.
>
> Suppose it were perfectly certain that the life and fortune of every one of us would, one day or other, depend on his winning or losing a game at chess. Don't you think that we should all consider it to be a primary duty to learn at least the names and moves of the pieces; to have a notion of a gambit, and a keen eye for all the means of giving and getting out of check? Do you not think that we should look with disapprobation amounting to scorn upon the father who allowed his son, or the state which allowed its members, to grow up without knowing a pawn from a knight?
>
> Yet it is a very plain and elementary truth that in life the fortune and the happiness of every one of us, and, more or less, of those who are connected with us, do depend upon our knowing something of the rules of a game infl-

nitely more difficult and complicated than chess. It is a game which has been played for untold ages, every man and woman of us being one of the two players in a game of his or her own. The chess-board is the world, the pieces are the phenomena of the universe, the rules of the game are what we call the laws of Nature. The player on the other side is hidden from us. We know that his play is always fair, just, and patient. But we also know, to our cost, that he never overlooks a mistake, or makes the smallest allowance for ignorance. To the man who plays well, the highest stakes are paid, with that sort of overflowing generosity with which the strong shows delight in strength. And one who plays ill is checkmated—without haste, but without remorse.

My metaphor will remind some of you of the famous picture in which Retzsch has depicted Satan playing at chess with a man for his soul. Substitute for the mocking fiend in that picture a calm, strong angel who is playing for love, as we say, and would rather lose than win—and I should accept it as an image of human life.

Well, what I mean by education is learning the rules of this mighty game. In other words, education is the instruction of the intellect in the laws of Nature, under which name I include not merely things and their forces, but men and their ways; and the fashioning of the affections and of the will into an earnest and loving desire to move in harmony with those laws. For me, education means neither more or less than this. Anything which professes to call itself education must be tried by this standard, and if it fails to stand the test, I will not call it education, whatever may be the force of authority, or of numbers, upon the other side.

There we have the whole thing—"the rules of the game"—oh, if we only knew and would observe them, so many, many lives would not be checkmated so early! Because he has not learned the rules of the game the savage is disappearing, cities are brought low, ships full of costly treasure sink beneath the waves, civilizations disappear, and untold and unnecessary anguish pervades many fair spots of the globe. Some peoples there are, like the Chinese, who by their breeding powers and ability to subsist cheaply cheat, as far as the race is concerned, the player on the other side of the table, but for most it means in the end extinction.

In this connection the writer begs leave to comment on some recent utterances of Professor John Dewey, the philosopher, a *griffin*[1] in affairs of the Far East, who writes as follows:

It helps to explain the conservatism of the Chinese, their *laissez-faire* reverence for nature and their contempt for hurried and artificial devices of man's contriving. Their minds are as steeped in contact with natural processes as their bodies are apt for agricultural work. They are conservative because for thousands of years they have been conserving the resources of nature, nursing, preserving, patiently, obstinately. While Western peoples have attached, exploited and in the end wasted the soil, they have conserved it. The results are engraved upon both Chinese and western psychologies. The Chinese have learned to wait for the fruition of slow natural processes. They can not be hustled because in their mode of life nature can not be hustled. Why be in a hurry when hurry means only vexation for yourself and either accomplishes nothing in nature or else interferes with its processes and so hinders the natural harvest? . . .

[1] A new horse running its first race.

The Chinese have almost more than any other people *wasted* their natural resources, particularly forests. As for their contempt for artificial devices, etc., what about the Chinese method of renitrifying the soil and rotation of crops, their coal briquets, etc.? Perchance Dr. Dewey has never read King's "Farmers of Forty Centuries." They do *just the things* he says they do not do. The present writer has great admiration for the Chinese, but he thinks their conservatism is carried too far. The world will never be improved by conservatives and fatalists.

As we are going to discuss geology in its relation to our present civilization, or we may say just civilization, it behooves us to define civilization. Not long since I saw a book, one of those illogical things the author of which adopts a sensational title to help "get it over" with the public; the title was "Civilization, Its Cause and Its Cure." To one who has seen the life of primitive peoples, civilization is not a disease and man is infinitely better off under so-called civilized conditions than under the conditions of savagery. While our civilization has many faults and is only one of many admirable civilizations, it is the opposite of savagery. It is that kind of life which is so ordered for the race as a whole that there is time and opportunity left over after the business of getting food and keeping warm and begetting offspring for the things of the mind and of the spirit, for games, for politics and sermons. Savages play little or not at all, their politics are simple and there is little evidence of introspection.

Granted, at least for the time being, that we have a civilization, which is not perfect, to be sure, and yet not so bad, what is the rôle of geology in that civilization? Well, in the first place, geology acquaints us with many of the "rules of the game" in nature. Physics and chemistry define them, but geology shows us how they have worked and are working to-day.

The three great basic industries, the tripod of our material well-being at least, are forestry, agriculture and mining. To this we might add fishing. There seems to be little question but that man studied forestry, in a crude way, of course, before he did either of the other two arts; next came agriculture, and last mining. In the earliest time he saw (and there was no need for him to) little relationship between geology, or the formations of rocks, and the forests, but to-day it is different. In my library is a book, a thick one, too, called "Forest Physiography," which, among many other interesting things, shows the relations between the character of the vegetation, types of trees, stand, etc., and the geologic formations. This is so important and large a subject that it is almost a separate and distinct science. There is such an intimate relationship that the writer has used the converse of this and mapped

geologic formations in certain places in the Philippines by noting the vegetation growing on them. In Surigao, Mindanao, Philippine Islands, on the very basic rocks whose weathering has yielded the extensive deposits of laterite, so rich in iron as to be classed as iron ore, the vegetation is peculiar and strikingly different from the rest of the lowland region. In eastern Oregon the valuable yellow pine forests grow on disintegrated basalt, while the pumice strewn stretches will support a growth of jack pine only.

Also in the Coast Range mountains of California, one can note a distinct change in vegetation between that growing on rocks of Franciscan (Jurassic) age and that on Cretaceous and Tertiary rocks, the change in many instances being quite sharp.

If, before buying a farm, you wanted to be perfectly sure of the kind of soil you had, you would naturally take samples to be analyzed. Much or little can be made out of these, depending upon how, when and where they are taken, but if you knew the simple geologic formations you could tell a great deal without resorting to the other method. Certain formations on weathering yield definite soil products, some good, others not so good. And, again, the drainage of the farm is an all-important factor, and even a rudimentary knowledge of the subject will tell you much. In the "good old days" before science was developed the farmer did not heed these relationships, but he can not afford to ignore them now. We in America pride ourselves on our agriculture, but a people (no other than the hated Germans) by scientific study of the soils have been able to increase the fertility of otherwise poor soils so that they get many more bushels per acre than our yield, and it might surprise a number of farmers to learn that "dry farming" has been practised on the Balearic Islands for hundreds of years. One of if not the most important commercial fertilizers is a geological product, the buried potash salt deposits of Alsace and Stassfurt and Wielicza. We, in America, are just beginning to utilize these soil replenishers.

Now when it comes to mining, the applications are too patent to need elaboration here. I may be pardoned for alluding here to the Benguet Consolidated Mine in the highlands of Luzon, one of the notable small gold mines of the world, but it will illustrate the connection, particularly since it shows the practical application of the work of the geologist. The prospects of that property in 1909, when it was wrecked by a typhoon and there was a question of whether or not it should be rehabilitated, depended upon determining three things: (1) What is the cause of its mineralization? (2) will the values continue in depth? and (3) to what depth? These things and others can be and were determined with a high degree of probability by a geological study of the region, and by

no other way, in advance of actual mining. The mining geologist has become an institution. How proud the profession is to-day of the achievements of the most eminent member of it! The writer is one with a goodly number who believes that when politics and social relations are studied scientifically then, and not till then, will confusion and blundering be displaced by peace and contentment. He is one, whether or not his views are shared by others, who believes that the particular type of training afforded by geology and engineering is greatly needed in the world to-day. The lawyers and preachers, professors and even the business men have had a turn and their work has been of value—but let us see what the engineer and the scientist can do. If they are given a chance, methinks a new era in politics will be upon us.

The rôle of the geologist in the great and fascinating oil game has been the theme of many magazine articles recently, and we hardly need to take the time now to repeat some of his exploits. Exactly what the oil geologist does when he is snooping around a supposed oil field, we shall not tell you now. Suffice it to say that he uses no magic, no incantations, but in their stead organized common sense, which is only another definition for science. Some people still find (or try to find) oil and water with divining rods, but concerns like the Standard Oil Company do not find that they can afford such wasteful and unscientific methods.

The writer has often told his classes in geology that if they knew all about the oil game they would have no difficulty in understanding much of the trouble between Mexico and the United States, and recently a professor of history told him, with tremendous enthusiasm, of a new way of writing history he had invented. He proposed to write history from the point of view of the great industries, such as oil, wheat, gold and other resources. I hope he will carry out his intention and if he does, it ought to be good history, too, because it will take into account the things that have made history, and we shall hear less of kings and politicians and heroes, and much buncombe will be got rid of. Lo! already we have the first of the new kind of histories—Wells's "The Outline of History." You will please note that in the "Outline" the writer goes back into geologic history, the only proper foundation for the understanding of human history.

There are besides these fundamental fields many activities of men which also are profoundly affected by geologic considerations, but these are not so evident as in the cases cited. The writer proposes to give a number of concrete cases which will, it is hoped, reveal the far-reaching effects born of a knowledge of this subject.

The first illustration is found in the field of engineering. Recently a railroad company was being sued by a firm of con-

tractors in an attempt to get a different classification of excavated material in the construction of a new line. With a different classification a higher rate of payment would have to be made. One of the main contentions of the plaintiffs was to the effect that a great body of material which had been classified as earth by the railroad engineer was shale, which would mean an additional payment of a good many hundreds of dollars. As a matter of fact—and the veriest tyro in the subject should have known it—there was no shale at all in that particular locality, it being *all adobe*, a stiff clay characteristic of the volcanic regions of the western United States. Most of the plaintiff's contentions were equally absurd, but for downright foolishness, the statement made by the "geologist," so called, to the effect that a certain body of material was "clay in the winter and shale in the summer" excels anything any freshman in our college classes has ever said.

Suppose I were going to engage in the business of foreign trade, would it not be a very necessary thing to know what foreign countries possessed in the way of raw materials and manufactures before investing too heavily in equipment? Raw materials are generally geologic products, and fuels are also very necessary and these, too, are geologic products, coal and oil being the most important. Whether it be petroleum or diamonds, bauxite or asbestos, copper or phosphates, tantalite or sulfur, one is dependent upon geology; that is to say, where, how they occur in the rocks, and in what quantity. This is commercial geology. Two notable books along this line have appeared recently which no statesman or student of world affairs can afford not to read. They are "Commercial Geology," by J. E. Spurr, former consulting geologist for the Guggenheim Syndicate, and "The Strategy of Minerals," by Dr. George Otis Smith, director of the U. S. Geologic Survey.

Much has been written about scenery, and the older geologies, which were largely descriptive, developed this side to the neglect of some things which are now given more space in the text-books. Nevertheless, it is scarcely an exaggeration to say that only one tourist in a hundred knows, much less appreciates, the history of the Yosemite Park region, the story of a bit of chalk from the white cliffs of northern France, the reason for the thousand and one little lakes in northern Wisconsin and Minnesota, or the full meaning of that chain of snow-capped peaks along the crest of the Cascades. That famous region between Austria and Italy known as the Dolomites is a land only of crazy, jagged rocks to many of that restless horde which, formerly at least, used to crawl like ants over and about those limestone pinnacles.

The human stream flows on from year to year over mountain and across plain, by glaciers and through oil fields, but little know

or care they about cirques, moraines, faults, anticlines or diatomaceous shales. The great teeming book of Nature is for them little more than a Gideon's Bible in a hotel bedroom. The trouble is this, that the average tourist is on his way—in a gas-driven buggy—and he cares more about arriving than about what is along the road.

Here is where geology, if given a chance, might and would wonderfully enrich the pleasure and profit of the traveller. The writer vigorously protests against the assertion of some artistic and temperamental individuals that they alone see the beauties of Nature, that the scientist with his "mania for knowing *why* kills the joy in the picture." There are some beauties in nature which the artist and the poet do not and never will see. Furthermore, the painter usually studies a limited landscape while the geologist views and tries to interpret a picture embracing worlds of space and eons of time. The scientist sees all the poet sees and more, because he understands what he is looking at.

In contrast to the old "public be damned" policy, there is a great solicitude to-day on the part of certain public utilities for the safety of the people. This has not come about rapidly nor without the force of public opinion aroused by several horrible holocausts which might have been averted to a certain extent. One of these was the so-called San Francisco fire. It is amusing to hear the rather childish contention of the real estaters and some other business men of the booster type in San Francisco that the fire, not the earthquake, did the damage. Any one at all acquainted with the facts knows that had there been no earthquake the fire probably never would have started, and secondly, it almost certainly would not have got beyond control had not the water mains been wrecked by the earth movements. The earthquake did it and the Spring Valley Water Company, whose reservoirs and mains were located along the well-known (to geologists) San Andreas fault, was rendered impotent; San Francisco, dependent upon this source of water, was, therefore, at the mercy of the flames which had been started by overturned stoves, chimneys, etc.

Later, Los Angeles built a fine new aqueduct, bringing water two hundred and fifty miles from the Sierras, and, having learned from experience, provided for just such emergencies.

Wonderful is the work of the Italian geologists in Calabria and Sicily in this branch of geology, but that is another and longer story.

Every now and then, although not as frequently as of old, some dam breaks and a town is wiped out. The Johnstown, Pennsylvania, disaster comes to the minds of those over twenty-five years

old. Nowadays, the geologist and the diamond drill are lessening the number of these dread possibilities.

The facts of deeper significance relating to the conduct of the Great War are just now coming to light and some tales of exploits not so spectacular but none the less thrilling are becoming known. One of these (which *was* spectacular) relates to the activities of geologists and mining engineers in some stupendous mining operations at Messines Ridge, where a most important strategic position occupied by the Germans was literally blown off the map through the scientific knowledge of the masters of earth science.

Another case, cited by ex-President Cross of the Geological Society of America, tells of the need of the American military officers for knowing the source of the stone used in German concrete work and how a petrographer, with his microscope, identified the particular kind of rock which was known to geologists to occur at a certain locality mapped prior to the war.

The brilliant utilization by Von Hindenburg of both his own study and that of the Russian geologists of the Mazurian Lake region is generally known. This campaign of Von Hindenburg stamped him as one of the foremost masters of scientific warfare brought to the fore by the Great War. That campaign alone has done much in my own mind to dispel the odium which the adjective German has attached to his name. He was on the wrong side, but he was none the less a brilliant strategist, perhaps the most brilliant of all the generals on any side, judging from his methods.

Up to this point we have considered only those applications of a so-called practical nature. The main theme of this discussion is, to the writer at least, far more interesting and far more important. It is that body of facts or data which can be correlated with the intellectual life and with the things of the spirit. The difficulty many people find in arriving at a rational philosophy of life is due to the fact that they have no adequate perspective; they have no true conception of time or space and our relation to each of these concepts. A great many people are rattling around in their houses like peas in a pod with nothing to which they may anchor. They are the prey of whims, superstitions and every unkind gust of the chilly winds of adversity. Not only are many of the human species drifting aimlessly, but their vague foundationless philosophies have long since faded out of the horizon, leaving many of the poor deluded earth children discouraged, others disillusioned and resentful. And so, when a poor, blundering world drifts foolishly, but helplessly, into a great international strife, we see half-crazed people try all sorts of social nostrums and political quackery. Religion itself fails to lend support perhaps for the reason that it is perverted and much of it is not real.

Once I wondered if there was any practical value in the study of paleontology aside from the use of fossils as indicators in stratigraphic studies in connection with coal and oil investigations. Since the great war, however, I have turned to the history of life, as revealed by this study and have found more real comfort and more genuine arguments against pessimism than I have gained from any other modern source. To me paleontology is one of the most practical studies in our curriculum to-day. Had Treitzke been a student of history in the largest sense of the word and not merely of that comparatively short chapter known as human history, he would have arrived at some radically different conclusions. It was he and Nietzsche with their myopic vision who misled the Prussians into thinking that they could succeed in a game that never has succeeded since the world began.

Where to-day are the Trilobites, the fighting crustaceans of the Silurian seas? Where the gigantic Ammonites of the Mesozoic? (I once saw the four-foot—diameter—shell of one of these monsters in Von Zittel's museum in Munich). The Nautilus, a comparatively small and simple cousin of this "bruiser," still lives in the warm seas. Where is the Pterodactyl? Even the present monarch of the air, the eagle, lives a lonely and vanishing life. What availeth the enormous strength of the gorilla? He hides now when puny man comes after him through the jungle. Where are the Caesars, the Alexanders and Pharaohs—where are the Huns of the sea and land and air of all history? Remember the Dinosaurs! Ruthlessness! what were you not going to do in a terror-stricken world! When the Prussian monster "superman" bellowed and spat fire, man at first did tremble, but the cry of a crucified Belgian babe aroused the world to arms to go out to meet this super-fiend and it was soon decided, this contest. The answer was, "Powder River" and a dethroned Kaiser. It is the same old kind of a fight which has been waged since the beginning of the world, only now it is moving to its culmination. The law of the jungle has been appealed to a higher court.

Ever since the onset of the Russian proletariat rebellion there have been indications of a world-wide revolt on the part of certain elements against civilization, as one writer would put it. This is not, as he thinks, a revolt against civilization, but against *our* civilization or *our order;* and half the world is panicky. Of course, this *is* a serious thing for certain classes who could not exist except for this system, but viewed in the large there is no cause for alarm as to the ultimate welfare of civilization. Geology and her sister, or shall we say daughter, science, paleontology, furnish us accounts of many such *apparently* catastrophic changes, but *always* a higher type of animal and civilization have succeeded the older.

The Bolshevik, the protestant, is the rule in geological history—without him there would be no change. The immediate change he brings about is not always pleasant or even good, but it has led and does lead to better conditions and a higher type of life. It is not the survival of the fit but of the *unfit* and discontented that has caused progress and brought about a better régime. All history, both geologic and human, proves this.

Why should I in my egotism whine because it looks as if the white man were facing a losing fight with the colored races? If the "Great Race" passes, it will be because a greater race will shove it aside. The torch of civilization (though not necessarily our own cherished kind) will continue to burn even if Fifth Avenue is overrun by the Sons of Abraham or the Golden Gate some day becomes a mere vista in a Japanese *kakemono*. Civilization will not die because *we* won't breed and must have twin-sixes instead of twins. Do not make the mistake and infer that the writer wants to see the "Great Race" superseded. He does not. As a white man, he does not like the prospect, nor does he have any immediate fear of it, but whether we like it or not, old Dame Nature is going on with the play according to her own rules and we can not stop the action by pouting and swearing about it out in the lobby.

Before this digression we were speaking of religion. It is far from my mind here to suggest something to take the place of true religion for the reason that there is nothing capable of doing this. But the fact remains that some people have not been able to recognize religion or have been driven from it by the blunders of some theologists and their champions.

Just now we are witnessing a miserable and lamentable recrudescence of the old controversy between the theologists and the scientists, this time started by William Jennings Bryan and staged in the good old state of Kentucky. Nothing will be gained by arguing these matters with people who ignore the facts, but if this sort of thing is kept up it will make that state the laughing-stock of the world and will prove a boomerang to the religious zealots and in the end will only hurt the cause of true religion. The amazing thing about this latest episode is the revelation of the amount of ignorance, misunderstanding and blind prejudice that still persists in the world. At a time when we thought we were making real progress along certain lines this comes as a shock.

There comes to mind here the name of one person, the best known and loved name in all the State of Oregon, Condon. The late Dr. Thomas Condon was formerly a missionary sent out to the Dalles when it was a mere trading post. He soon drifted out of this field into that of geology and became the first state geologist. His contributions to the geology of the state were, for his time and

training, notable, but his great contribution to the intellectual and spiritual life of the state lay in his strong advocacy of the theory of evolution at a time when most of the state was in ignorance of it and fought it. He was virtually excommunicated by the theologists, but his life and intellectual honesty have left an impress upon the state which has scarcely been equalled.

Not long since a venerable teacher and a good man came to me and frankly confessed that he got no comfort from so-called religion and he felt doubtful about the promises of the church. "What," he said, "has your science, these fossils and stones, to offer? What do they tell about the future, a world to come? Is there *any* evidence whatsoever that will give us hope?" And then I thought and thought and racked my brain and finally I said, "No, nothing that you and the world will accept as evidence. Those fossils, those granites and slates, all speak the language of the past. They tell of worlds, time worlds, that are dead. No, I can do nothing for you, can give you no comfort." And then he left me with a sad face, and I, too, was dissatisfied. And long I pondered these questions and in time there came to me bit by bit, slowly at first, but later more rapidly and clearly, a vision of things as they really were.

Aforetime they were wont to teach that this old world was hasting toward a condition of refrigeration, to a time when no more life could exist on the planet. That was a theory which could not stand the searchlight of advancing knowledge. At best it was a hopeless, pessimistic sort of doctrine and for that reason alone it had no right to last. On the other hand, cosmogonists are slowly accumulating facts which go to show that the world is improving as a place in which to live.

In the same class with this old worn-out doctrine of a cold, dead world is another doctrine of one particular school of biologists, which we believe is equally hopeless, namely, the dictum of Weismann. Here again the trouble arises from insufficiency of perspective, lack of facts. This particular school of biologists—slaves to German thought—deny the inheritance of acquired characters, citing the old stock argument about cutting off cats' tails. As can easily be seen, these are mutilations and not characters acquired through function.

If we look back through the vast stores of potent facts accumulated by paleontologists, particularly through the researches of Alpheus Hyatt and of Cope, and of the later researches of the biologist Guyer, we are faced with an increasing array of evidence in support of the theories of Aristotle and Lamarck and little to comfort the Weismannians.

But you are wanting to know, naturally, where this leads us. It leads us to a reasonable philosophy of life, one that is more in

keeping with that taught by Jesus, the Nazarene. For those who must have something more to bolster up their shaking faith we say, "Build upon the work of Chamberlin, the cosmogonist, and Lamarck, the paleontologist." The one testifies to the permanence of the habitability of man's dwelling-place, the other to the possibilities of heredity and education, of salvation through character. Let us here draw upon the felicitous expressions of Chamberlin, a major prophet of our time—to him the Lord still speaks as He did to Moses and Elijah of Old:

The long perspective of the past should afford at least some suggestions of the future, but it must be confessed that the most important previsions are dependent on interpretations of the past that have not yet emerged from the tentative state. A word has been said relative to a possible return of a glacial epoch, but this is contingent on agencies that are yet matters of hypothesis, and no sure prediction can be offered. Question has been raised as to whether the end of the recent period of deformation has come and a gradation into another period of quiescence and equable genial conditions has begun; but the answer hangs on the doctrine of periodicity of deformation and quiescence which does not yet command universal assent, and if it were given, there would remain the further question whether the period of deformation is completed. The duration of the earth as a habitable globe has been a common theme of prognosis. A final doom of the race has been a favorite theme for quasi-scientific romances. But this all hangs on the doctrine of a former molten earth, if not also more remotely upon the doctrine of an origin from a gaseous nebula. Under the alternative conception of a slow-grown earth, conserving its energies and giving forth atmosphere as there is need for it, conjoined with a more generous conception of the energies resident in the sun and the stellar system, no narrow limit need be assigned to the habitability of the earth. A Psychozoic era, as long as the Cenozoic or the Paleozoic, or an eon as long as the cosmic and the biotic ones, may quite as well be predicted as anything else. The forecast is at best speculative, but an optimistic outlook seems to us more likely to prove true than a pessimistic one. An immeasurably higher evolution than that now reached, with attainments beyond present comprehension, is a reasonable hope.

The forecast of an eon of intellectual and spiritual development comparable in magnitude to the prolonged physical and biotic evolutions lends to the total view of earth-history, past and prospective, eminent moral satisfaction, and the thought that individual contributions to the higher welfare of the race may realize the fullest fruits of their permanent worth by continued influence through scarcely limited ages, gives value to life and inspiration to personal endeavor.

THE DEBT OF MEDICAL SCIENCE TO THE EARLY PRINTERS

By Dr. JAMES J. WALSH

THE art of printing, that is, of using movable type to multiply copies of manuscripts, was, as is well known, taken up enthusiastically all over Europe immediately after its invention. It is a surpassing tribute to the progressive enterprising qualities of the men of the middle of the fifteenth century, when the Middle Ages, usually thought so unprogressive, were drawing to a close, to note in how short a time the new art was brought to perfection and came to be recognized in all the civilized countries. In the course of a few decades, indeed within scarcely more than a single generation, there were printing presses and printers' establishments turning out volumes in all the modern languages as well as in Latin and Greek, many of which have been precious monuments ever since. We are rather proud of the fact that the telephone "caught on" with such rapidity in our time, but the use of printing spread quite as rapidly in the mid-fifteenth century. The telephone is a convenience for business, while printing has always been, until abuses came in our time, the handmaid of literature and science.

The history of printing for the forty years before the discovery of America shows very clearly that men were not lacking in initiative in the long ago whenever a worthwhile stimulus came to arouse them. What is most interesting, however, for us here is the supreme scholarliness with which the new art was applied. We are in the midst of a flood of utterly trivial and often absolutely useless material that pours from the press at the present time in the form of books and periodicals. By contrast it is a never-ending source of surprise to see how these earliest printers devoted themselves to the perpetuation and publication of the best things that had been circulating in manuscript. Above all, the value of the recently invented mode of easy book-making as a means of rendering the precious works of the older times available for ever so many more readers than before was recognized and taken advantage of with a promptness and a thoroughness which demonstrate quite conclusively that the early printers, as a rule, looked upon their vocation as a profession rather than a trade. No amount of trouble seemed too much for these men to take in order to send forth worthy products from their presses. In all the countries the most important members of the new craft felt that they were working for the

benefit of mankind, not only in their own generation but for the generations to come, rather than in any sense of the word merely giving themselves and their time and labor to an occupation by which a living was to be made, much less any large amount of money to be accumulated. A great many of these early printers were scholars deeply intent on the education of their generation and the affording of every possible provision for the ready contact of the men of their time with the most valuable products of the human intellect that had been written in preceding generations.

Almost needless to say, compared to printing in our time the making of printed books in that first generation after the invention of movable type was an extremely slow, laborious process. It is true that the new mode of book-making was almost infinitely superior to long hand-writing in the multiplication of copies of books, yet it was so far below what we have come to make of printing in facility that it is very dubious if the most persistent of the men of our time would have the patience and the diligent industry necessary for any such issuance of printed books as poured from the presses of the earlier Renaissance period. Fortunately, the first printers had before them as examples of book-making the very beautiful manuscript volumes of the immediately preceding period, when some of the most charming books ever made had been produced entirely by hand. Now that we in our time have come once more to know these marvelous manuscript copies very well and are perforce compelled to deep admiration of them, we can understand better the expression of a great Italian bibliophile of that first generation of printing, who, having a magnificent collection of manuscript works refused to buy any of these "machine-made books," as he contemptuously called what must have seemed to him the cheap, new-fangled volumes which were just coming into vogue.

There was one very decided advantage in the difficulties of early printing and the time-taking pains demanded by printed book-making in the pioneer days. No one felt like devoting the time and trouble and energy required for getting out a book, to say nothing for the moment of the expense, to any work that was not worth all that had to be put into it. Later, it became so easy to print books, indeed it was, until the recent war came to raise the price of print paper, such a comparatively cheap and almost entirely mechanical series of processes to print and bind them that all sorts of trivial trash was accorded the dignity of appearance in book form and granted the full freedom of bookdom. The result is that we are fairly overwhelmed with printed volumes, most of them destined to be almost literally ephemeral, the creatures of a day. It has accordingly become a matter of no little difficulty for readers to avoid wasting time over some of the worthless books and

almost more difficult to be able to choose with assurance those that are worthy of time and attention. No wonder that there has been serious discussion of the question whether the printing press really conferred a benefit on mankind or not.

There is only one compensation in our mechanical book-making, and that is the fact that there is a minimum waste of time and energy on the many valueless subjects of it, and most of them are destined to a very brief existence. When book-making was cheapest at the end of the nineteenth and beginning of the twentieth century and above all when for a time we were experimenting with wood-pulp paper with the idea that it might replace better stock in book-making, we made a large number of very perishable books, the leaves of which fairly crumble in the hands now and that are evidently going to fall to pieces before long. A devout follower of William Morris once declared in connection with this, "Thank God that most of these cheap books which were born yesterday will be dead to-morrow, and thank God for the wood pulp paper they are printed on, for they will crumble to pieces in a few years and we shall not have to give them space on our library shelves."

Almost needless to say, the Renaissance printers thought entirely too much of books for their own sakes to treat them in any such fashion as this. They used the very best paper stock, fine carbon ink, substantial binding, and their books, if anything of this kind may be expected to last, would seem destined to immortality if only accorded a modicum of care. That is the reason why now in the midst of the growing interest in incunabula of all kinds so many men, even though not of the millionaire class, can enjoy the privilege of having some of them in their libraries.

The Renaissance printers in choosing books that would be worthy of time and labor they had to devote to them displayed eminently critical good judgment. In spite of the difficulties presented, practically all the great classics were in type before 1500, and though scholars had to be procured, sometimes even from a distance, to edit them and the collation of manuscripts at times distant from each other had to be made, nothing daunted, the printers proceeded to get out these *Editiones principes*, those princely first editions which have meant so much as a rule ever since.

So far as the classics were concerned, it was almost as easy to choose the authors that should have the honor of early printing, as it is in the modern time to make a five foot shelf of books really worth while. When it came to choosing the volumes that should be printed apart from the classics, a heavy burden of responsibility in the choice was placed upon the early printers' shoulders, and it is marvelous to look back now and see how well they bore up under

it and succeeded so well in solving the problems which it involved. In nearly every department of thought they succeeded in picking out those contributions to human thinking that were best worth while preserving for future generations and making as readily available as possible for their own a reasonably large collection of incunabula in a marvelously representative compendium of most of the best thought of humanity down to the Renaissance time.

In medicine this is particularly true and the early printers, especially in Italy, presented the world with a collection of medical and surgical books unsurpassed in interest, enshrining some of the greatest thinking that had been done down to the Renaissance time. Most of these existed in a number of manuscripts so that it was comparatively easy at that time to print them in authoritative and authentic editions. Had there been any delay in the printing of them the neglect of manuscript materials which began in the second half of the sixteenth century would almost surely have brought about a disappearance of many important books, the printing of which preserved them very effectively. We have only come to realize in recent years how many volumes, important not only for the history of medicine but as illustrating how our professional colleagues of centuries ago anticipated some of our best thoughts, might have been lost only for the zeal and the scholarship and the excellent critical judgment of these early Renaissance printers. Medicine owes them an immense debt which we can repay only by worthy admiration of their work in these succeeding centuries.

Another very valuable feature of their work was that the printing was done in such magnificent editions that their great books were considered valuable for themselves quite apart from the interest of the medical or surgical material which they contained, and accordingly they were preserved as precious treasures of the printing art, when the ebb tide of interest in later medieval medicine and surgery set in. For there came a time not long after the invention of printing when the people of the later Renaissance began to talk of everything before the Renaissance as "the Dark Ages" and when the word Gothic was invented and applied to things medieval with the implication that all that was done before Greek and classic Latin were introduced into the modern world was quite unworthy of the classic period and to be considered as representative only of the barbaric ancestors called by the single contemptuous term the Goths. These older writings in any less valuable material form might very well have disappeared. Gothic applied to literature, to some extent at least, as well as to architecture. The poetry, the philosophy and the art of the medievalists were supposed to be no more worthy of admiration but on the con-

trary to be scoffed at quite as much as the architecture. No wonder there was danger of medieval literary works disappearing. With the return of admiration for Gothic architecture the other medieval modes of thought have come into their own of admiration and proper appreciation once more. In the meantime their value as magnificent examples of the printers' art had saved many of them from neglect and probably from destruction. This was particularly true of the early printed editions of the medical books of the Middle Ages in the strict sense of that term and also of the popular medical books and especially books of reference containing articles on medical subjects. For several centuries the contents of these books was supposed not to give them a value that would make them worth while preserving, but their quality as achievements of the early printers gave them a special significance and made them precious.

Our own great surgeon general's library, beyond all doubt the best medical library in the world, possesses a whole series of these books, probably the completest collection of its kind in the world. A surprise to any one unaccustomed to seeing copies of these early printed books is the magnificent character of the volumes. They are beautifully printed on fine paper, substantially bound, and in spite of the vicissitudes of time for what is now nearly five hundred years, they are in excellent condition. After all, when anything made by men is still in good shape for use after half a millennium it may be considered a permanent enrichment of the precious heritages of the race. When it is constructed of such materials as paper and leather, usually thought of as rather perishable, and yet carries its message after a dozen of generations, there is no doubt at all that the men who made it secured a triumph in the mingling of the useful and the beautiful. Horace said, Qui miscuit utila dulci omne tulit punctum—"he who mingles the useful with the beautiful carries off every point." Surely the great Latin poet's expression applies nowhere with more propriety than to this question of the place of distinction deserved by the printers of the medical books of the fifteenth century.

Medical Incunabula

An excellent idea of the critical judgment of these early printers in selecting medical works for reproduction will be derived from the fact that the well-known "Regimen Sanitatis Salernitanum" went through no less than twenty editions before the end of the fifteenth century. We have come to realize how precious were the hygienic precepts laid down in this little volume, collected, some of them at least, very probably by the professors of the medical school of Salerno as early as the twelfth century. Twenty editions

seems a very large number for a book in the very first generation of printing, but as it is probable that more than 300 editions of the "Regimen" have been printed since, it would seem as though these early printers had established an average which succeeding generations were to try to maintain as they came to appreciate the little book properly. This story of the manual of health of Salerno is of itself a striking testimony to the value of incunabula. A book that was as popular as this must not only have been widely read, but must have produced deep effects. There are few more sensible collections of rules for health than are to be found in this little volume, so that its influence for good must have been immense, and it furnishes a new point of view for the history of medicine.

The labor and expense to which they were willing to go in what they considered the worthy printing of medical books is very well illustrated by the Ketham (John of Ketham) 1493 edition of Mondinus or Mondino, the well-known anatomical teacher and writer of the fourteenth century. There is a picture of a lesson in dissection reproduced in this volume in four colors by means of stencils. The faces of the attendants are so vivid and lifelike that it seems clear that they must have been taken from the life. Subsequent editions are distinctly inferior. This first edition made at the height of the Renaissance is worthy in every way of the time in which it was made, and there are other illustrations and one famous feminine anatomical figure drawn from the subject, the first of its kind, which shows that the printer went for his illustrations to some one of the distinguished artists of the time and not to some hack worker who had recognized the opportunity for money-making in connection with art work for the printer and given himself to that new profession. Even when there are editions of these volumes later than 1500, printing and illustrations are still under the influence of the early spirit and represent better work than in most of the subsequent times.

What a precious incentive for the men of the Renaissance time, intent on making scientific as well as artistic and literary advances, to have before them the works of the men who represented the experience of the earlier middle ages, for instance, when the full tradition of Hippocrates and Galen still lived on and was applied by men who weighed discriminatingly and tested clinically the hints as to diagnosis and treatment received from the old-time Greeks. It would have been too bad, indeed, if the works of such men as Aëtius, Alexander of Tralles and Paul of Aegina had not been available for the consultation of Renaissance scholars. All these knew their Greek classic medicine and were themselves making important observations. Their works were thoroughly appreciated, as is easy to

understand from the expression of Cornelius (16th century) with regard to Aëtius, for he declared that the easiest way to get a summary of all that the old physicians had recommended and the old surgeons attempted was to "find it in Aëtius." It was particularly valuable to have these writers made available just when the growing knowledge of Latin and Greek made consultation of them possible by a great many physicians, for teachers, at least of medicine, in the Renaissance days were almost as a rule very scholarly individuals thoroughly up to date in their educational interests.

It was doubtless because of the existence of this important clientèle that the editions of the early medieval Greek medical authors were made. Paul of Aëgina and Alexander of Tralles are full of practical hints that must have been eminently suggestive in the medical and surgical practice of the enterprising members of the medical profession in the Renaissance period. Alexander, for instance, has a very interesting and thoroughly modern treatment of consumption. His prescription for consumptives was "an abundance of milk with a hearty nutritious diet as digestible as possible." Besides this, he recommended change of air, suggesting a stay at a watering place or a sea voyage.

We have come back to a great extent to Alexander's way of looking at epilepsy. He recommended a plain simple diet with regular bowels and special attention to the gastro-intestinal tract. Baths were recommended and regular exercise and sexual abstinence. He rejected treatment of the condition by surgery of the head either by trephining or by incisions or by cauterization. He insisted above all that the physician should not depend on any single method of treatment for disease, but "should be an inventor and think out new ways and means by which the cure of the patient's affection and the relief of his symptoms may be brought about."

One of the most important of what may be called the extraneous factors in the development of medicine which have been preserved for us by the early printers is Nicholas of Cusa, an edition of whose works in two volumes probably was printed before 1476. He was a Roman cardinal very much interested in science, who declared that "the earth is a star like other stars, is not the center of the universe, is not at rest nor are its poles fixed." These declarations were made before 1450. He was particularly interested in certain medical problems, and in his dialogue "On static experiments," which he wrote in 1450, suggested obtaining the comparative weights of the blood and urine at various ages and in various diseases, for the weight with the color would tell him more than the color alone. He also suggested that the pulse should be counted

a hundred times in various patients under varying conditions of health and then the weights of water which ran through a clepsydra or water clock, for other clocks were not readily available, should be compared. He has been hailed, as a consequence of this and similar suggestions with regard to the counting of the respiration and with regard to the therapeutic value of various pharmacal materials by means of their specific gravities as well as other physical qualities, as the pioneer for the use of definite scientific or laboratory methods to secure greater accuracy in diagnosis and dosage.

Surgical Incunabula

Surgery is even better represented among the cradle books than medicine. One of the volumes that well deserves a mention among the incunabula is the edition of Guy de Chaulaic, issued at Venice in 1480. He was the first of the great medieval surgeons thus to be given the dignity of print some fifteen years before the others were accorded the privilege, but surely no one would deny him the right to this distinction. Few men have ever written more valuable material with regard to surgery for their own time and for many succeeding generations than this great Papal physician who, after having studied in Italy, taught at Montpellier and then sat down, knowing the writings on surgery that had been made before his time, to give his generation a real textbook. The man who said that a man who practiced surgery without knowing anatomy was like a blind carpenter sawing wood was emphasizing fundamentals in the right way. He dwelt on the fact that the great hamperer of progress in medicine was thoughtless following of others without studying the subject for one's self and finding out just as far as possible just exactly what conditions were. No wonder that he has been held in high honor by the French ever since, and that all the world has come to agree with them in their reverence during the last few generations.

What a loss it would have been to the history of surgery if that notable incunabulum, the *Cyrurgia,* printed by Andrea Torresani de Asule at Venice in 1499, had failed for some reason to be printed. It contains the textbooks on surgery of Bruno of Longoburgo, of Theodoric, of Roland and of Roger of Bertapaglia, the great Italian surgeons of the thirteenth century, as well as of Lanfranc and of Guy de Chaulaic, the French surgeons who came a little later.

Only that we have this or some similar printed record it would have been quite impossible for our generation to believe that surgeons seven centuries ago had anticipated so many ideas in surgery that we are inclined to think of as representing modern dis-

coveries and inventions. The practice of surgery sank to such a low ebb in the first half of the nineteenth century that no one would have believed that what these professors of surgery at medieval universities relate as their experiences were anything more than fairy tales if anybody had tried to retell them a century ago or so. Had they been kept only in manuscript form, almost surely all knowledge of them would have disappeared because of not only the utter lack of interest but even the contempt in which they would have been held had their contents been noted at any time for nearly two centuries in the modern period. As it is, they were saved for us by the printers of the Renaissance and now are available to teach us the precious lesson that whenever men set their minds and hearts to solving human problems they solve them very well in spite of the difficulties there may be in the way. What is needed is the will to solve them.

These old surgeons operated extensively, daring to invade even the three great cavities of the body, the skull, the abdomen and the thorax, the last, at least in a limited way. Their operations upon the skull for the raising of depressed bone were very thorough and yet conducted with a delicacy of technique that saved the patient from further harm, and they recognized such conditions as linear fractures and the possibility of fracture by *contrecoup*. Their opening of the skull is not surprising, for of course a great many of the savage nations of the world have done trephining for one reason or another, but what stamps the work of the medieval surgeons in this regard is the completeness of the technique which they suggest. Their operations within the abdomen, especially for wounds in the intestines, which must have been rather common in the hand-to-hand conflict and sword play of the time, form another matter for surprise to those who think of these abdominal operations as developing only in our day. Some of these surgeons describe the use of metal tubes to keep the intestines patulous while the healing process was going on, and the Brancas, father and son, in surgery, developed the use of the trachea of animals for their intestinal anastomosis, because this would not have to be passed out of the body, but would be gradually dissolved in the secretions, though not until ample time had been allowed for healing. They used strong wine as the only dressing and got union by first intention and boasted of it. Their treatment of compound fractures is extremely interesting, because any one who will refer to the textbooks on surgery of scarcely more than a generation ago will find what an opprobrium to modern surgery the treatment of compound fractures was and how many men preferred to amputate rather than take the risk of pyemia which was so often involved.

They insisted particularly that proper nutrition was an extremely important element for the healing of small as well as great wounds and that therefore the surgeon must know what is likely to be of assistance to his patients in these regards. Theodoric declared that:

> The physician must, above all, not be ignorant of the kind of food materials that generate good chyme and good blood. Out of such materials the wounded man must be fed, in order that a suitable diet shall bring about a restoration of health and the renascence of the flesh and the restoration of the continuity of the wound.

I have told in an article in the *Annals of the History of Medicine,* Vol. II, No. 1, the story of what these surgeons did for the development of laryngology and rhinology seven centuries ago. It was not until the end of the nineteenth century here in America—indeed most of the original work was done here in New York City—that these two specialties developed once more. How far their development had gone in the older time is well preserved for us in this Venetian *incunabulum* which enshrines so much of the medieval surgical experience. There are descriptions of how to remove the tonsils and the uvula if that is deemed necessary, and how to treat even retro-esophageal abscess and edema of the glottis. Bruno, usually called of Longoburgo because of his birthplace, who taught at Verona and Padua and who finished his textbook of surgery, the "Chirurgia Magna," at Padua in January, 1252, describes several varieties of nasal polyps, and above all differentiates one of them as a malignant tumor. His description of it shows his clinical powers of observation, for he says that it was of darker color, of slight sensibility and very hard. His conservatism was demonstrated by his advice that it should not be operated upon, for operation only hastened the growth and led all the sooner to the death of the patient. Bruno insisted that obstructions of the nose should be removed and suggested a number of technical details to facilitate this, including cauterization.

The one thing that the modern generations can well be extremely sorry for is that the early printers never got a chance to print Marcantonio's "Anatomy," illustrated by Leonardo da Vinci's plates. There is, I believe, a letter of Leonardo da Vinci extant in which he says that he was working at a book on anatomy. We had no idea at all until the present generation how much work he did at it. Altogether, many hundreds of plates of dissection have been found made by Leonardo da Vinci, and they represent the best things of their kind that were done down to Vesalius's day, nearly a full half century later. Indeed, in certain ways Leonardo's pictured dissections are ahead of those of Vesalius, and they possess

the added merit of the great artist's wonderful power of visualization. Had the early printers secured an opportunity to print this we would have had probably the most precious incunabulum in the world. As it is, Leonardo's plates were left to be printed for the first time full four centuries after he made them, though he actually finished them within practically a generation after the middle ages and had done some of them before the middle ages closed, if one were to take as the date of that the discovery of America, as some historians seem inclined to do, in recent years.

Some of the medical and surgical incunabula are among the most beautiful printed books ever published. The examples in the library of the New York Academy of Medicine illustrate that. What a curious contradiction of the ordinary impression about progress in mankind and its supposed constancy and above all its tending to a climax in our time is to be found in the history of printing. Some of the most beautiful printed books ever issued were printed in the first generation of the history of printing. Indeed, I think it may well be said that some of them were printed in the first ten years after the German method of the use of movable type became an open secret. Toward the end of the nineteenth century, on the other hand, we were doing some of the vilest printing that has ever been done in the history of the art. Vile means cheap, to be sold for a low price and that is what most of our books literally were made for. When William Morris, disgusted with the cheap paper, the indistinct type faces, the bad spacing and the poor impressions, set about the reform of printing and proceeded to make some beautiful editions, he went straight back to some of the very earliest printed books and imitating them in every particular, from the hand-made paper and the type faces to the spacing and the margins, revived the cult of beautiful pages once more and brought us back to the printing of a time that is now coming to be nearly 500 years ago.

Popular Medical Information

An extremely valuable feature of the work of the early printers for medicine consisted in the printing of the old encyclopedias or popular sources of information which had been circulating in manuscript sometimes for centuries, representing better than anything else the interests of educated people and at the same time served to show what was the knowledge which the majority of them possessed from which to draw their practical conclusions on a great many subjects. It is easy to understand that medicine and subjects related to it would occupy no inconsiderable place in these old-time encyclopedias. It has been rather the custom to think that most of

what was contained in popular information with regard to medicine in the older time was absurd. Indeed, it has been a favorite commonplace of writers with regard to popular medicine in the middle ages and especially those who made short references to it out of a comparatively small amount of information to emphasize the utter absurdity of popular medicine notions, particularly six or seven centuries ago.

Undoubtedly, there were a great many absurdities in medieval medicine, but then it is beyond all doubt that there have been absurdities in medicine at all times. We have had an abundance of them in our time. Even our generation has been caught two or three times by the idea that testicular tissue from animals might very well serve to renew man's vitality, and we have wanted so much to have some such fountain of youth that we have been tempted beyond our strength to take up some of the most absurd ideas. There are good honest physicians and surgeons who insist that, while there may be and probably is some valuable idea underlying the theory of the vaccines, there is no doubt at all that the use of these has been carried to absurd lengths, and then of course we have had all sorts of drugs that have come and gone, most of them absolutely inert, fortunately, but not a few of them harmful to some degree at least and yet used for a time by physicians, and not infrequently adopted and advertised by the irregulars on the strength of professional commendations until large amounts of money were expended for them. The glass in our modern therapeutic houses is entirely too thin for us to afford to throw any stones at the absurdities of medieval therapeutics.

What is surprising, however, in the books of popular information provided for the medieval period is the amount of valuable details of ascertained knowledge which these old encyclopedists presented and which formed the mental pabulum for information seekers some seven centuries ago. This is true for a number of these old tomes.

Probably the most famous of them is the "Speculum," that is, The Mirror, in the sense of something that you look into in order to find what you want, of Vincent of Beauvais. Ordinarily, it would be assumed that encyclopedias in the middle ages must have been very brief in size compared to ours, partly because there was not enough information known to make large volumes and, secondly, because interest in them was not sufficient to encourage the making of them. Vincent had, however, that scholarly monarch, Louis IX, who did so much for the University of Paris and especially the Sorbonne, for patron, and that fact supplied the necessary stimulus as well as the means, and so the great Dominican encyclo-

pedist was able to employ a number of his fellow Dominicans as assistants and they made a magnificent encyclopedia. It has been calculated that the "Speculum Majus" contains as much material as would be comprised in some fifty octavo volumes in the modern time. No wonder that it was called "Bibliotheca Mundi," "Library of the World," in the old time. The book was such a favorite that, in spite of the immense labor involved in copying such a huge work, there is scarcely an important library in Europe which does not contain one or more manuscript copies of it and it was evidently available to all who wanted to consult it in every important center of intellectual interest in Europe.

The date of the *editio princeps* is not absolutely known, since, like all the other early printed books, it is issued without date, but it is calculated to be some time between 1463 and 1470. The original edition is magnificently printed with fine, clear type faces, good spacing, easy to read, apart from the abbreviations which occur in the text, beautifully rubricated, the whole on precious hand-made paper, with wide margins, the pages remaining without discoloration from any disintegration of the paper even to the present day. It could only have been a labor of love that would dictate this magnificent form for so huge a work, considering the labor and expense which the early printers had to give to it, and yet it must have been issued in a good large edition, for there are a great many copies of this earliest issue still preserved, and I suppose there must be a dozen or perhaps a score of them here in America.

The French Universal Dictionary calls attention to some of the details of information in Vincent which are usually supposed to be much later in origin. For instance, the rotundity of the earth and the existence of antipodes are both treated as established facts. It is suggested that if a stone were to be dropped through a hole made through the earth's sphere it would come to rest at the center of the earth. He points out that superheated steam digests animal tissues, anticipating something of Papin's work, and he was familiar with many details of physiology usually supposed to have come much later.

Another of these old encyclopedists, whose work was issued in a series of magnificent editions as *incunabula*, is Bartholomaeus Anglicus, known as Bartholomew, the Englishman, or Bartholomew of Glanville, who wrote a work called in the original Latin *De proprietatibus rerum*, "On the Properties of Things." This was probably completed some time about the middle of the thirteenth century. It was written to provide information for priests in the fulfillment of their various ecclesiastical duties as preachers, advisers, confessors and, as a modern writer has suggested, would

probably be called in the modern time "The Clerical Repertory for the Interpretation of Holy Scripture." Almost needless to say, this would require no little attention to the diseases of mankind, and as a matter of fact the seventh book is taken up with the question of the ailments of men, *De infirmitatibus.*

This came to be one of the most popular books in Europe, consulted by practically all the intellectual folk when information was desired. The University of Paris kept two copies for public use, the one for the consultation of "poor teachers of the Sorbonne" (teachers' salaries have always kept them poor) which apparently might be borrowed for a time and taken to the teacher's room, while the other, intended for the students, was chained to a desk in the college chapel, representing one of those chained books of which so much was said when it was thought that the Bible was the only chained book. It is extant in numberless manuscript copies, and there have been many editions of it in print. Father Plassmann of St. Bonaventure's College, Allegheny, N. Y., who reviewed the whole subject of the authorship of the book and found the clue through the unfortunate confusion of the true name and date for the author, calls attention to the many translations of the book into the vernacular languages of Europe. There were versions in French, one of them famous as a literary monument of the French language, into Flemish, Spanish and English as well as the Provençal. The translation into English was printed by Wynkyn de Worde and is said to be the *chef-d'oeuvre* of this press. There is a tradition that Shakespeare was familiar with this volume, and that not a few of his curiosities of information with regard to natural history are due to consultation of it.

Very probably the most interesting paragraph for physicians in Bartholomew is his summary for priests of what he thought proper for them to know with regard to the insane. His paragraph is, I think, one of the most striking brief compendiums of what should be known about the insane that has ever been written. I doubt if any one in the modern time could write a better summing up of knowledge, real knowledge due to observation as to the insane, than Bartholomew has given. I quote the paragraph in the quaint translation given in "Medieval Lore" (London 1893), which is taken from a very old English version, sometimes thought to be the one that Shakespeare consulted:

Madness cometh sometime of passions of the soul, as of business and of great thoughts, of sorrow and of too great study, and of dread: sometime of the biting of a wood (mad) hound, or some other venomous beast; sometime of melancholy meats, and sometime of drink of strong wine. And as the causes be diverse, the tokens and signs be diverse. For some cry and leap and hurt

and wound themselves and other men, and darken and hide themselves in privy and secret places. The medicine of them is, that they be bound, that they hurt not themselves and other men. And namely, such shall be refreshed, and comforted, and withdrawn from cause and matter of dread and busy thoughts. And they must be gladdened with instruments of music, and some deal be occupied.

These are only a few items in the long accounts of what medicine owes to the early printers. Perhaps our appreciation can be measured by the prices which medical incunabula, to say nothing of other "cradle books," command at the present time. If that is a measure, then we are not inappreciative, but on the contrary our recognition of the work of these men can be measured highly in that most important standard of values of our day, the money of the realm. Try to buy some of the incunabula and see what you are asked for them and you will understand present-day appreciation better than I could tell you.

OCCUPATIONS IN THE UNITED STATES

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THE record of the changes in occupation in the United States as reported in two censuses, 1910 and 1920, may be of temporary interest as a measurement of the economic changes during the interval between the two periods, or it may have a more permanent value if the shifting of labor from one group of industries to another shows over a number of years a persistent trend. Whatever their value, the rearrangement of some of the tables of the fourteenth census of the United States, particularly in this instance of those of the abstract of occupation statistics, brings into prominence some changes which have been known or long suspected and others that are little realized.

THE GROUP SUBJECT TO OCCUPATION

Table I, which gives statistics from 1880 to 1920 inclusive, shows that the percentage of population over 10 years of age has increased from 73 per cent. in 1880 to 78 per cent. in 1910, and no further increase is recorded in 1920. If there is any proper ratio which

TABLE I

Year	Total population	Population over 10 years	Per cent. of Total	Per cent. of population over 10 years old gainfully occupied
1880	50,155,783	36,761,607	73	47.3
1890	62,622,250	47,413,559	75	49.2
1900	75,994,575	57,949,824	76	50.2
1910	91,972,266	71,580,270	78	53.3
1920	105,710,626	82,739,315	78	50.3

ought to be maintained between the group over 10 years old and the total population, in order that the race may properly perpetuate itself, the writer does not know it. Certainly, the percentage of persons over 10 years old can not go on increasing indefinitely. Two or three queries arise from the table. Is the increase in percentage of population over 10 years old to the total population due to an influx of adult foreigners? Is the lack of increase in the percentage over 10 years old in 1920 the result of the restriction of immigration? Does the increasing percentage of the population over 10 years old mean a gradually lessening birth rate? Or does

the lack of increase in this population in 1920 reflect the losses in war due to casualties and the return of the foreign born to add to the man power of the armies of their native land?

It would appear that the influx of adult population aided the increases of the population over 10 years of age and also was a factor in the lack of increase in the percentage between 1910 and 1920, but it can not account for the full amount of these increases. Table II shows the immigration for ten-year periods from 1880 to 1920, with the number of children below 14 years of age during the last two decades.

TABLE II

Immigration in 10 years per 1000 initial population	Decade	Total immigration during the 10 year period	Number of children under 14 years
104	1881–1890	5,246,613	
61	1891–1900	3,844,420	
116	1901–1910	8,795,386	1,058,541
62	1911–1920	5,735,811	814,377

In the two periods, 1901–1910 and 1911–1920, the percentage of children to the total immigration was about 12; these referred to children under 14 years and in the latter period for a few years it included the children under 16 years. If figures were given for children under 10 years the percentage would have been much smaller. In Table I, the percentage of children under 10 years ranges from 22 per cent. to 27 per cent., which, taken in comparison with the percentages of immigration above, shows a marked percentage in favor of adult immigration.

In Table III, which gives the proportion of males to the total immigration, it will be seen that the proportion has constantly increased with the exception of the year 1914 which registered a slight decrease, possibly as a wartime factor. In general the older migrations to this country appear to be by families, and the newer less so. Even in the later years, certain races, the Hebrews, Germans and English, have migrated by families rather than by adult males; but these are largely offset by the newer group of immigrants who have apparently been represented by the men of the families.

TABLE III

Years	Percentage of males to total immigration
1893–1895	61.5
1896–1900	63.5
1904–1905	69.2
1914	65.4

On the other hand, the lack of increase for 1920 (Table I) in

the percentage over 10 years old can not be ascribed in any large degree to the restriction of immigration; and in a less degree can the cause be found in the return of native sons to the aid of the land of their birth. Table II shows that while the immigration for the decade, 1911 to 1920, was less than that of the decade, 1901 to 1910, it was greater than during any previous decade. Table IV

TABLE IV

Years	Aliens departed
1908	395,073
1909	225,802
1910	202,436
1914	303,338
1915	204,074
1919	123,522
1920	288,315
1921	247,718
1922	198,712

gives the number of departures for selected years between 1908 and 1922 covering the wartime period. This table leads Mr. J. C. Welliver[1] to remark that the report of a great return of aliens to Europe to take part in the war was very much of a fiction. Mr. Welliver also calls attention to the sum of the departures during 1915 and 1916, which was 333,839; while the average yearly departure during the four years previous was 310,000.

One other factor must be admitted to explain the constantly increasing population over 10 years old. Table V lists the number of families and the size of the family from 1850 to 1920.

TABLE V

Census year	Number of families	Persons to a family
1850	3,598,240	5.6
1860	5,210,934	5.3
1870	7,579,363	5.1
1880	9,945,916	5.0
1890	12,690,152	4.9
1900	16,187,715	4.7
1910	20,255,555	4.5
1920	24,351,676	4.3

The family in this instance is the "economic family," not the natural family, and it may vary from a person living alone to the entire population of an institution. The summary of the census on dwellings and families states that "it is believed, however, that the changes in the average size of census families from decade to decade, as well as the variations in this respect among the geographic divisions and states, are due mainly to differences in the size of private families and particularly in the number of children."

[1] Judson C. Welliver, "World migrations and American immigration," *Amer. Rev. of Rev.*, LXVIII, No. 403, Aug., 1923, 193–200.

One is safe, then, in the conclusion that the main factors in the increasing percentage of the population over 10 years old are adult immigration and the decreasing birth rate.

Gains and Losses in Occupations, 1910–1920

Table VI shows the numbers engaged in the various occupations in 1920 and the percentage of the gains (+) and losses (—) recorded over the 1910 figures. The classification is the one adopted by the 1920 census, which is "occupational rather than industrial."

TABLE VI

Occupation	Per cent. loss or gain	1920 totals
All occupations	+ 9	41,614,248
1. Agriculture, forestry and animal husbandry	— 14	10,953,158
2. Extraction of minerals	+ 13	1,090,223
3. Manufacturing and mechanical industries	+ 21	12,818,524
4. Transportation	+ 15	3,063,582
5. Trade	+ 16	4,242,979
6. Public service (not otherwise classified)	+ 70	770,460
7. Professional service	+ 30	2,143,889
8. Domestic and personal service	— 10	3,404,892
9. Clerical occupations	+ 79	3,126,541

It will be noted that in the large groups of this table losses were sustained in the agricultural group and the domestic service group. Both of these losses have been generally recognized; the former by constant references to the diminution in farm labor by newspaper and magazine articles, and the latter by the inability of housekeepers to obtain domestic help with the ease prevalent in 1910. On the other hand there are very large increases in the clerical occupations group and the public service group, with normal increases in the remaining groups. In order to better analyze the situation abbreviated tables are presented showing the distribution in detail of the sub-occupations under the larger classifications of Table VI.

Agriculture, Forestry and Animal Husbandry

Table VII indicates a great increase in foremen and a great decrease in laborers. Second to these are the increases in lumbermen, raftsmen and wood-choppers and the decrease in fishermen and oystermen. In these four cases there seems to be justification for the explanatory note of the Census Bureau stating that the loss in agriculture may be due to the change of time in taking the census. The 1910 census was of April 15, and the 1920 of January 1, and since farm labor is a seasonal occupation and January the dull season, a loss may be expected, inasmuch as a large number of farm laborers may have been missed or assigned to other occupa-

TABLE VII

Subheadings of agriculture, forestry and animal husbandry group	Gains or losses per cent.	Totals so occupied 1920
Dairy farm, farm, garden and orchard foremen	+ 82	93,048
Lumbermen, raftsmen, wood choppers	+ 27	205,315
Gardeners, florists, fruit growers, nurserymen	+ 22	169,399
Owners and managers of log and timber camps	+ 6	8,410
Dairy farmers, farmers, stock raisers	+ 4	6,201,261
Garden, greenhouse, orchard and nursery laborers	+ 3	137,010
Other agriculturist and animal husbandry pursuits (apiarists, poultry raisers, bailers, etc.)	— 8	401,599
Fishermen and oystermen	—24	52,836
Dairy farm, farm and stock farm laborers	—37	4,041,627

tions by the enumerators in 1920. That there is some justification in this attitude is upheld by the tables in the gains established by other seasonal occupations, particularly in lumbering and wood-chopping; and also by the losses in the number of fishermen and oystermen. Just how effective this change of time was in affecting the numbers in the occupation mentioned may be judged from the following table (Table VIII).

TABLE VIII

Occupation	Numbers in 1890	1900	1910	1920
Agricultural pursuits	8,565,929	10,438,219	12,659,082	10,953,158
Agricultural laborers	4,410,877	4,459,346	6,069,321	4,041,627
Fishermen, oystermen	60,162	73,190	68,275	52,836
Lumbermen, wood-choppers	65,866	72,190	161,268	205,315

The change in the census period has been made twice recently; in 1900 the enumeration is of July 1. The change from July to April did not apparently cause a diminution in the agricultural laborers, even though July is the busy time for agricultural work. On the other hand, the increases and decreases in the other two industries appear to be radically affected by the seasonal factor.

Extraction of Minerals

This group, which registered an increase as a whole of 13 per cent., has individual occupations ranging from an increase of 213 per cent. to a decrease of 9 per cent., as shown by Table IX.

TABLE IX

Subheadings of extraction of minerals group	Loss or gain percentage.	1920 totals
Oil, gas and salt well operatives	+213	91,022
Foremen, overseers and inspectors	+ 54	36,931
Operators, officials and managers	+ 36	34,325
Coal mine operatives	+ 19	733,936
Quarry operatives	— 4	45,162
Operatives in other mines (lead, zinc, etc.)	— 9	41,162

The great increase in the production of oil in recent years would

make the increase of 213 per cent. in oil and gas well operatives easy of acceptance. Possibly, as in the case of the other industries of Table VII, the decreases in the last two items under mining operations may be due to the seasonal feature of the industry.

Manufacturing and Mechanical Pursuits

TABLE X

Subheadings of manufacturing and mechanical pursuits group	Loss or gain per cent.	1920 totals
Cotton mills—semi-skilled operatives	+ 102	302,454
Iron and steel industries (semi-skilled operatives)	+ 87	689,980
Machinists, mill wrights, tool-makers	+ 83	894,622
Iron and steel industries—laborers	+ 51	729,613
Carpenters	+ 8	887,379
Clothing industry (semi-skilled operatives)	+ 6	409,361
Lumber and furniture industries—laborers	+ 1	320,613
Painters, glaziers, varnishers, etc.	— 2	323,032
General building laborers	— 28	623,203

This table has been abbreviated to include only those occupations in which the total numbers engaged exceeded 300,000. Altogether, there are 29 different types of workers in the list. The cotton semi-skilled operatives head the entire list with the biggest gain; this is followed in turn by the food industry laborers, with a gain of 94 per cent. and the managers and superintendents in manufacturing establishments with a gain of 93 per cent. At the foot of the list with a loss of 47 per cent. are dressmakers and seamstresses; then come the general building laborers tabulated above, then the clay, glass and stone laborers with a loss of 19 per cent. and the brick and stone masons with a loss of 18 per cent.

Transportation

TABLE XI

Subheadings of transportation group	Loss or gain per cent.	1920 totals
Garage keepers and managers	+ 740	42,151
Chauffeurs	+ 535	285,045
Telephone operators	+ 94	190,160
Switchmen, flagmen, yardmen	+ 23	111,565
Brakemen	+ 23	114,107
Locomotive engineers	+ 14	109,899
Laborers, steam and street railways	— 13	495,713
Hostlers and stable hands	— 70	18,976
Livery stable keepers and managers	— 70	11,240
Carriage and hack drivers	— 76	9,057

In this table the substitution of the automobile for the horse is indicated, and the allied occupations have moved in keeping with the general trend. In the 1900 census, the automobile did not appear as a source of occupation; in 1910 there were 45,785 chauffeurs and 35,376 carriage and hack drivers. This change in transportation, which is of course very evident, has occurred with great suddenness; and in addition the spread of the automobile is much more extensive than that of the horse-drawn vehicle ever was.

TRADE

TABLE XII

Subheadings of trade group	Loss or gain per cent.	1920 totals
Laborers in coal and lumber yards, warehouses, etc.	+ 54	125,609
Bankers, brokers and money lenders	+ 52	161,613
Insurance agents and officials	+ 37	134,978
Laborers, porters and helpers in stores	+ 22	125,007
Salesmen and saleswomen	+ 20	1,177,494
Real estate agents and officials	+ 18	149,135
Retail dealers	+ 11	1,328,275
Clerks in stores	+ 7	413,918
Deliverymen	— 26	170,235

This is the nearest normal of any group listed. The entire group has had an increase of 16 per cent., which is about the average increase expected. The excesses in this group are less than in any other. The loss in deliverymen between 1910 and 1920 is indicated in a footnote of the census report as probably due to the substitution of motor for horse-drawn delivery wagons.

PUBLIC SERVICE (not otherwise classified)

TABLE XIII

Subheadings of public service group	Loss or gain per cent.	1920 totals
Soldiers, sailors and marines	+ 192	225,503
Other pursuits; life-savers, lighthouse keepers, etc.	+ 108	21,453
Laborers (public service)	+ 57	106,915
Officials and inspectors	+ 51	80,334
Firemen—fire department	+ 42	50,771
Marshals, sheriffs, detectives	+ 36	32,214
Guards, watchmen and doorkeepers	+ 35	115,553
Policemen	+ 32	82,120
Officials and inspectors (city and county)	+ 6	55,597

The increase of 192 per cent. in soldiers, sailors and marines is easily accepted as a war hold-over. The gain of 108 per cent. in other pursuits, of which life-savers and lighthouse keepers are mentioned, is somewhat misleading. Life-savers, which form only 2,287 of the group, increase less than 6 per cent., and lighthouse keepers (1,463) suffered a loss of about 4 per cent. The gain was the result of "other pursuits" and is not specified.

PROFESSIONAL SERVICE

TABLE XIV

Subheadings of professional service group	Loss or gain per cent.	1920 totals
Trained nurses	+ 82	149,128
Semi-professional pursuits (notaries, healers, welfare workers, etc.)	+ 79	116,555
Technical engineers	+ 54	136,121
Teachers	+ 27	761,766
Clergymen	+ 8	127,270
Lawyers, judges, etc.	+ 7	122,519
Physicians and surgeons	0	150,007
Musicians and teachers of music	— 7	130,265

It is probable that the increase in trained nurses is a war resultant; possibly the larger call arising from the widespread epidemics of influenza, the increased wages resulting from the scarcity of nurses during and directly subsequent to the war, and the change in the hours or working day for nurses. The increase in the so-called semi-professional pursuits is due in large measure to the welfare worker class, which numbers 41,078 of the total given for this sub-group and which increased in ten years by about 150 per cent. During the war there was a great shortage of teachers, and daily it was reported that schools had to be closed because there were no teachers available. The loss sustained at that time must have very quickly righted itself, because in January, 1920, the gain over 1910 is given as 27 per cent. This gain is a little above the average gain for all pursuits and about the average gain for this group.

Domestic and Personal Service

TABLE XV

Subheadings of the domestic and personal service group	Gains or losses per cent.	1920 totals
Elevator tenders	+ 60	40,713
Janitors and sextons	+ 58	178,623
Billiard room, dance hall, etc., keepers	+ 50	24,897
Restaurant and lunch room keepers	+ 40	87,987
Waiters	+ 22	228,985
Housekeepers and stewards	+ 17	221,612
Midwives and nurses (not trained)	+ 16	156,769
Barbers, hair dressers, manicurists	+ 10	216,211
Porters (except in stores)	+ 5	88,168
Boarding and lodging house keepers	— 20	133,392
Servants	— 20	1,270,946
Launderers and laundresses (not in laundries)	— 21	396,756
Laundry, owners and officials	— 31	13,692
Laborers (domestic and personal service)	— 38	32,893
Bartenders	— 64	26,085
Saloon keepers	— 75	17,835

In general this group suffered a loss of 10 per cent. during the period. The gains above 20 per cent. show an extension of certain types of occupations which are characteristic of the times. The losses in this group are interesting; first, the loss in domestic service which arose rapidly following the war and which reflects probably the idea of servant as contrary to a liberty-loving people, and the losses sustained because of the prohibition amendment to the constitution.

Clerks in this table refer to shipping clerks, weighers and the like. Agents, canvassers and collectors are given an increase of 68 per cent., but this is made up of an increase of 156 per cent. in agents, with decreases in the numbers of canvassers and collectors. The interesting part of the table refers to accountants, which is

CLERICAL OCCUPATIONS
TABLE XVI

Subheadings of the clerical occupation group	Gains and losses per cent.	1920 totals
Clerks (except clerks in stores)	+ 109	1,487,905
Agents, canvassers and collectors	+ 68	175,722
Stenographers and typists	+ 66	615,154
Bookkeepers, cashiers and accountants	+ 50	734,688
Messengers, bundle and office boys and girls	+ 4	113,022

relatively a new occupation or better an old occupation with a great increase of business because of statutory demands. Accountants and auditors increased in the 10 year period to 201 per cent.

THE LOCALIZATION OF THE MEDIAN PLANE OF THE EMBRYO[1]

By Professor T. H. MORGAN

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THE eggs of many animals appear under the microscope to be radially symmetrical around a primary axis. This axis is an imaginary line extending from that region on the surface at which the polar bodies are given off (pole) through the center of the egg to the opposite pole (antipole). Sometimes the pole is indicated by the distribution of pigment or by some structure at the surface. The materials of the egg are stratified or graded from the pole to the antipole.

Other eggs have a bilateral structure. These eggs are always inclosed in a thick coat or cuticle (insects, squid). The median plane of the embryo corresponds to the plane of symmetry of the egg, but whether an innate bilateral structure of the protoplasm has determined the bilateral shape of the egg, and hence that of its coat also, or whether the shape of the egg coat, determined by the parent, gives shape to the enclosed protoplasm, has never been satisfactorily determined. It is true that many references could be gathered from the literature to show that embryologists have not hesitated to assume at times that there is present in all eggs, before fertilization, a real bilaterality whether they show it or not in their external form. Many statements could be cited that seem to mean that a bilateral structure (or "principle") exists in the egg cytoplasm which is the determining factor in locating not only the first planes of cleavage, but also the plane of bilaterality of the embryo. But how such bilaterality could direct or determine the position of cleavage furrows has never been explained, nor has it ever been made clear how such a postulated bilateral structure, were it present in the egg, could bring about the later differentiation with reference to a median plane.

It has been shown that the early divisions of the egg may sometimes bear a definite relation to the planes of symmetry of the embryo. It is, therefore, necessary to examine thoroughly the evidence that bears on this relation in order to find out whether the location of the cleavage planes determines the position of the embryo on the egg, or whether its position is independent of the cleavage.

[1] Chapters from Experimental Embryology. II.

The Relation of the Cleavage Planes to the Axes of the Embryo

The earliest observation showing the coincidence between the first plane of cleavage and the median plane of the body of the embryo was that of Newport in 1851. The position of the first cleavage in a frog's egg was recorded. The egg was left undisturbed until the neural folds appeared. Newport found that the median line between the folds corresponded with the mark indicating where the first cleavage plane had been. This observation has been repeated by at least ten later observers, who have, on the whole, confirmed Newport's observation. This relation can be determined only if the egg remains entirely undisturbed during the 40 to 60 hours between the first cleavage and the appearance of the neural folds. As a matter of fact, the egg does not remain stationary throughout this time, for during gastrulation the center of gravity of the embryo shifts so that the egg rotates. If, however, as appears to be the case, the egg rotates in the plane of the first cleavage, the original orientation may still hold, but if there are any irregularities in the process of gastrulation, these might cause the embryo to shift out of line. When the neural folds have been distinctly outlined, the embryo develops cilia over its surface that cause it to rotate within its membrane, and from this time onwards, there is ample opportunity for a change in position. The record of the position of the median plane must be made, therefore, as soon as possible. When all these precautions have been taken, it is found that there are still exceptional cases in which the two planes in question do not coincide. This was first observed by Roux ('83), then by Schultze ('99), Hertwig ('94), Morgan and Tsuda ('94), Kopsch ('95), Brachet ('04). The later observations have shown that when the first plane of cleavage does not cut through the middle of the gray crescent (see below), the median plane of the embryo corresponds with the crescent rather than with the first cleavage plane. The experiment of Brachet in which one of the first two blastomeres was injured, in cases where the first plane of cleavage did not coincide with the median plane of the crescent, confirmed this conclusion. It appears, therefore, that it is not the first cleavage itself that introduces a bilateral basis for the later development, but, on the contrary, the bilaterality of the frog's egg is already determined by the median line of the gray crescent that appears soon after fertilization and before the first cleavage appears. Therefore the question of fundamental importance is to determine what factor in the egg of the frog is responsible for the appearance of the gray crescent on one side of the

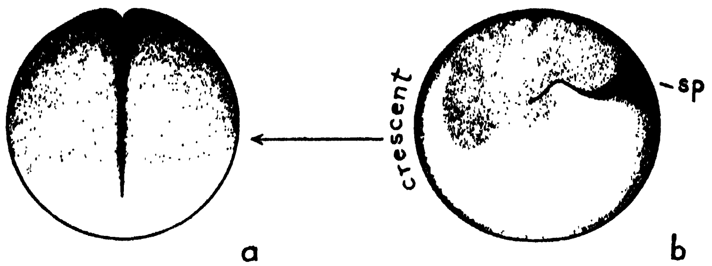

FIG. 1.

egg (Fig. 1, b). There is still the problem as to why the first plane of cleavage generally cuts through the middle of the crescent (Fig. 1, a), but for our present purpose this is a question of secondary importance. Before discussing further these problems in the frog's egg, the relation of the first cleavage plane to the median plane in other eggs may be examined.

In the salamander, *Diemyctylus viridescens,* the second cleavage corresponds to the median plane of the embryo according to Jordan's ('93) observations. A similar relation was found by Spemann ('01) to be the rule at least for the European salamander (Triton). In neither case has a gray crescent been observed, although it is possible that a change, similar to that which produces it, may take place but not be visible on the surface. By tying a

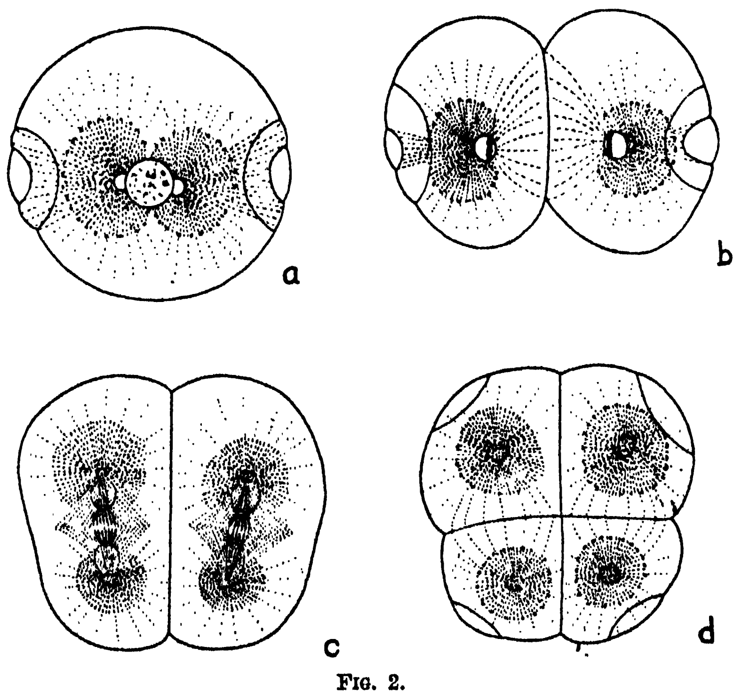

FIG. 2.

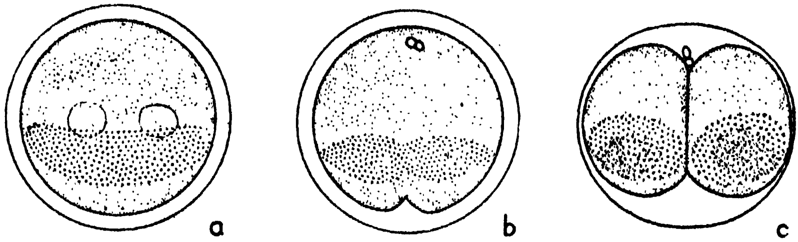

FIG. 3.

ligature around the egg at the time of the second cleavage and in that plane, Spemann found that double headed embryos can often be produced, owing to the partial splitting of the material into two parts. By further constriction, two whole embryos result which is not, as a rule, the case when the egg of the salamander is constricted in the first plane of cleavage. The result furnishes experimental evidence that, in this case, it is the second cleavage, and not the first that usually corresponds to the median plane of the embryo.

In 1884 Van Beneden and Julin published a detailed account of the cleavage of the egg of the ascidian Clavelina (Fig. 2). They observed that the first plane of cleavage coincides with the later median plane of the embryo. Chabry ('87), Seeliger ('85), Castle ('94) and Conklin ('05) have confirmed this relation for the eggs of other ascidians. Conklin has found in another ascidian Styella that immediately following fertilization a crescentic shaped accumulation of yellow pigment appears on one side of the egg (Fig. 3, a). The first cleavage (Fig. 3, b, c) passes through the middle of the yellow crescent.

The cleavage of the ascidian's egg takes place with almost no variation in the position of the successive planes of division and in the sizes of the resulting cells. In this respect it differs from the frog's egg, in which there is much variation, especially after the third cleavage. Since there are no sufficient observations as to the results that take place when the first cleavage of the ascidian fails to coincide with the crescent, we have no means of deciding whether the crescent or the cleavage plane is the basis for subsequent bilaterality.

Finally, it has been shown by Clapp ('91) and by Morgan ('93) that there is no definite relation between the first or second plane of cleavage of the fish's egg (Fig. 4, b, c), and the median plane of the body. Miss Clapp determined this for the large fixed egg of the toad fish and Morgan for the small pelagic egg of Ctenolabrus, and the somewhat larger eggs of Fundulus. The floating pelagic eggs seem to be perfectly spherical, nor is there any plane of symmetry visible in the other larger fish eggs. What factor or factors

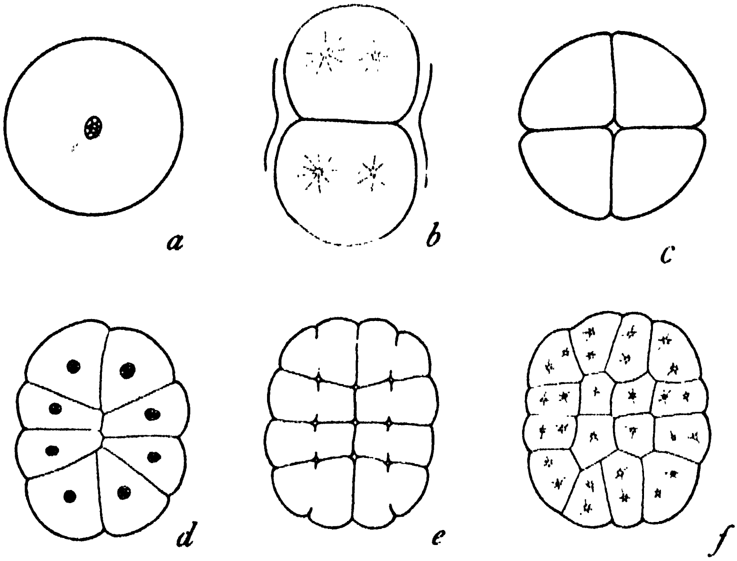

FIG. 4.

determine the median plane of the embryo is entirely unknown. The two-, four-, and eight-cell discs (Fig. 4, b, c, d) are at times bilateral in different planes, but this is apparently without significance for the later embryo. The many-celled disc of later stages appears to be again radially symmetrical.

EGGS WITH BILATERAL SYMMETRY BEFORE FERTILIZATION

In addition to the cases in which the egg before fertilization appears to be radially symmetrical around its primary axis, there are other cases in which the egg has already a plane of symmetry when it is fully formed. In these, the median plane of the embryo corresponds with the plane of symmetry of the egg. For instance, the egg of the squid has, according to Watase ('91), a strictly bilat-

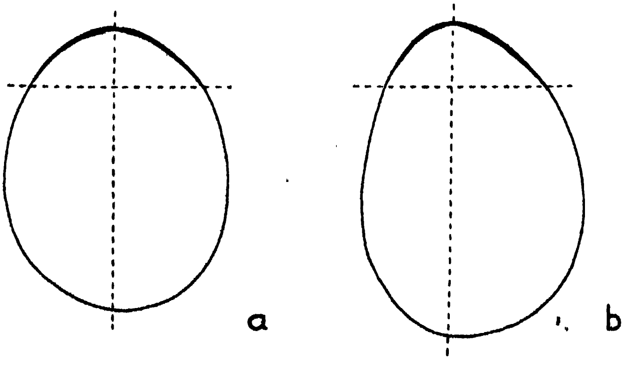

FIG. 5.

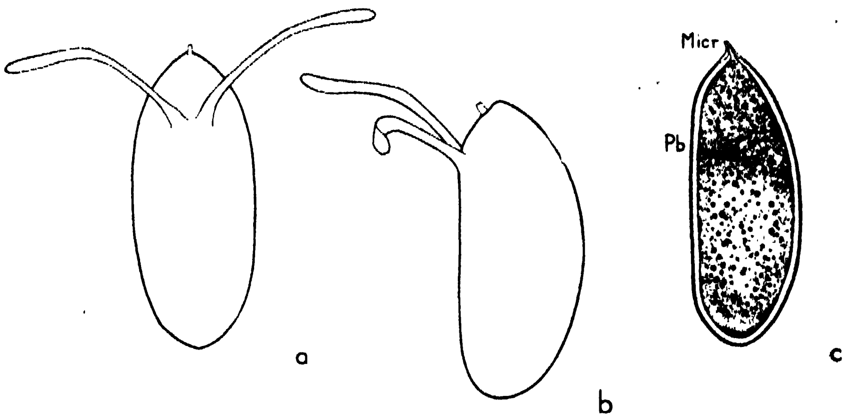

FIG. 6.

eral structure (Fig. 5, a, b). The first division is in this plane as is later the median plane of the embryo. It has not been shown whether the shape of the squid's egg is determined, in the first instance, by the shape of the follicle which surrounds it or whether it is determined by the protoplasm of the egg itself. It is also not known whether the first spindle places itself across this plane of symmetry, preparatory to the first division, in response to the shape of the egg, or whether other factors determine its position. Experimental evidence is lacking.

The eggs of many insects have a marked bilateral form (Fig. 6, a, b) which, in a way, corresponds with that of the mother's body. The anterior end of the insect's egg is not the point of the surface at which the polar bodies are given off. These lie anteriorly, but on the dorsal side of the egg at a point generally not very far from the micropyle of the egg through which the spermatozoa enter (Fig. 6, c, at Pb). The plane of bilaterality of the embryo corresponds with that of the egg.

The cleavage of the insect egg is centrolecithal, that is, the segmentation nucleus first divides into two nuclei and the daughter nuclei later divide again and again, but the protoplasm of the surface of the egg does not split up at this time. Only when a large number of nuclei have appeared, and have reached the surface, does the layer of protoplasm that covers the egg become constricted around these nuclei into a large number of cells. The bilaterality of the embryo proper can become apparent only when the embryonic organs develop out of this surface layer.

THE ORIGIN OF BILATERALITY IN EGGS THAT ARE RADIALLY SYMMETRICAL

From the preceding considerations it is evident that, in eggs

that have, before fertilization, a bilateral form, there is at present no way of deciding whether the shape is due to an inherent property of the protoplasm, or is imposed on the protoplasm by the maternal cells that produce the egg-shell. On the other hand, in eggs that are radially symmetrical around the primary axes before fertilization, there is evidence to show that bilaterality is introduced at the time of fertilization. It has been shown, for example, by Wilson and Matthews ('95), in the egg of the sea urchin, that the spermatozoon may enter at any point of the surface, and that its entrance determines the plane of the first cleavage, and since the bilaterality of the embryo coincides with the cleavage planes, it follows that the bilaterality is induced from the outside. In Nereis it has been shown by Just ('12) that the first cleavage cuts through the point of entrance of the spermatozoon and since the bilaterality of the embryo of Nereis has a definite relation to the cleavages, it follows here also that the bilaterality is superimposed from outside on a radial form. In the frog's egg it has also been shown by Roux ('83), Brachet ('03) and Jenkinson ('09) that the path of entrance of the spermatozoon coincides with the plane of bilaterality of the gray crescent (Fig. 1, b), and that this plane is also the plane of bilateral symmetry of the embryo. The gray crescent is not present in the unfertilized egg, but appears about an hour and a half after the sperm has entered.

These relations leave scarcely a doubt but that in these eggs—and they are typical of their kind—the bilaterality is induced from outside. I am inclined to think that this is also probable in the case of those eggs where the shell imposes on them from outside a bilateral form, although this is only an inference and has not yet been demonstrated by experiment or observation.

There are two further sources of evidence that relate to the origin of bilaterality in the frog's egg: (1) the origin of the gray crescent in eggs fertilized by two or more spermatozoa, and (2) the location of the crescent in parthenogenetic eggs. The former relation has been studied by Herlant ('11). If the unfertilized eggs of the frog are taken from the uterus and placed in concentrated sperm, many of the eggs are entered by two or more sperm. These sperm always enter in the black hemisphere apparently at any point. In dispermic eggs the gray crescent appears at the normal time and always between the two points of entrance of the spermatozoa, as shown in Fig 7. Hence, as in the normal egg, there is a definite relation between the points of penetration and the gray crescent, and the result is, in a sense, a compromise between the two influences acting at the same time. Whether a normal embryo results depends on special conditions relating to the division of the

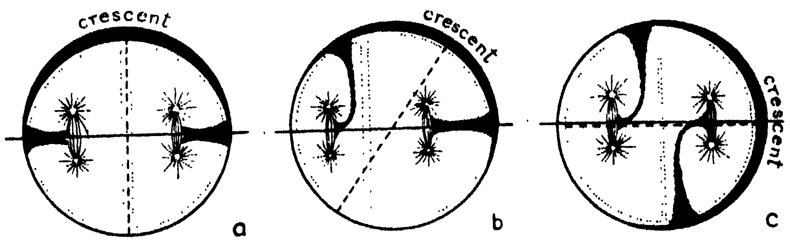

FIG. 7.

nuclei, but when an embryo does develop it stands in the same relation to the crescent as does the normal embryo.

When more than two spermatozoa enter an egg a single crescent also develops, but Herlant could not make out any relation between it and the entering points of the spermatozoa. Yet, in the light of the other evidence, it seems to me more probable that there is such a relation, rather than that, under these circumstances, the position of the crescent is predetermined in the egg structure itself, as Herlant suggests.

The origin of bilaterality in the parthenogenetic egg of the frog has been examined by Brachet. The development was started by Bataillon's method of puncturing the egg with a fine needle. In all eggs so punctured the gray crescent appears as in normally fertilized eggs, but *it has no definite relation to the point of puncture.* Only a small percentage of such eggs show a regular cleavage, and a still smaller percentage develop into embryos. In those that do, Brachet found that the embryo develops in relation to the crescent. He interprets the result to mean that the egg has a sort of labile bilaterality that may express itself in the egg alone, but which in normal fertilization may be altered into a new bilaterality by the entrance of the spermatozoon. In this respect he agrees, to some extent at least, with the older conclusion of Schultze, that the unfertilized frog's egg has an inherent bilateral structure; but Schultze also thought that it is not changed by the entrance of the spermatozoon. Personally, I do not think that one is obliged to draw the conclusion from Brachet's results that he has drawn. On the contrary, I am more inclined to think that the formation of the crescent in the parthenogenetic egg may have some definite relation to the internal changes connected with the development of the artificially induced cytasters that produce the mitotic figure for the first cleavage. Herlant ('13) has studied the origin of these cytasters and has shown that two or more develop in or near the path of entrance of the needle. Two of them, under optimum conditions, form the poles of the cleavage spindle. Their passage to the region of the egg nucleus may possibly induce the interior changes that

locate the crescent. It is true that this can not be shown to be the case at present, but in the light of the other evidence relating to the origin of bilaterality in the frog's egg, I am inclined not to ignore, at least, such a possibility.

The Position of the Chick in the Egg

The determination of the median plane of the embryo of the hen's egg, and the position of the embryo with respect to the shape of this egg has aroused a great deal of interest and speculation.

It has long been known that the young embryo chick lies, in most cases, across the long axis of the oval-shaped shell. If the large end of the shell is held to the left and the shell opened, the embryo is found on the upper surface of the yolk, with its head away from the observer in a great majority of cases (Fig. 8). The discovery of this relation goes back at least as far as von Baer (1828) and was probably known before his time, according to Bartelmez ('12, '18). The yolk on which the embryo lies is not spherical according to Bartelmez. Its longest axis corresponds with that of the shell. Its primary axis, extending from the embryo "downwards" through the center of the egg, is the shortest axis; while the axis in the third dimension ("horizontal") is intermediate in length. The yolk is surrounded by the spirally wound concentric layers of albumen, or "white," that have been formed as a secretion from the walls of the oviduct as the egg has passed down its length. The pointed end of the future "egg" is in advance, as the egg passes down the oviduct in a spiral path. This end may therefore be called the cloacal end and corresponds approximately to the right side of the later embryo. When the egg enters the oviduct it receives first the cloacal chalaza and then the opposite chalaza; these are fastened to the vitelline membranes and hold the egg in position, except in so

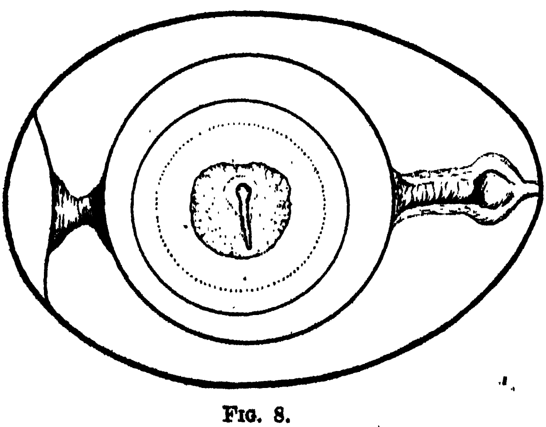

FIG. 8.

far as it rotates, as it progresses on the axis connecting the chalazae —the future long axis of the yolk. In other words, the egg keeps its pole always against the wall of the oviduct and the path of the pole inscribes, as it were, a spiral path on the wall of the oviduct.

It may appear that the shape of the yolk is due to the compressing layers of albumen which in turn are compressed by the hard shell. If this is the case the position of the embryo across the long axis might be supposed to be due to the shape of the egg, but this hypothesis alone fails to explain why the head is nearly always turned towards the same side of the egg. Since the two ends of the egg are of different shapes, one broad (where the air space comes to lie), and one pointed, it might appear at first sight that the resulting pressure relations might account for the orientation of the embryo on the egg, but again this suggestion will not explain why the head is nearly always directed towards a particular side.

Bartelmez, who has studied the egg of the pigeon in great detail, where the axial relations are the same as in the hen's egg, believes that the egg is bilateral before it enters the oviduct, and that one particular side of the egg enters first and this accounts for the orientation of the egg in the oviduct,[1] and also for the position of the embryo on the egg. In other words, he thinks that the ovarian egg has both a bilateral structure as well as a primary axis at right angles to this structure. His study of the early eggs, even before the yolk is laid down, led him to conclude that this bilaterality is expressed both in the excentric position of the nucleus (in regard to the primary axis) and in the elongation of the egg in one axis that corresponds to that seen in the oviducal egg, but the chances of error in such a determination must be very great.

The egg in the ovary is enclosed in a follicle that projects from the surface of the ovary as the egg enlarges. Its walls then develop a rich supply of anastomosing blood vessels, except over a crescent-shaped line, where the outer and inner layers of the follicles are fused with each other. This non-vascular crescent is known as the stigma, and according to Bartelmez the stigma lies nearly in the long axis of the egg. It develops, however, at a later stage than the supposed bilaterality of the egg, and he thinks follows it. According to Bartelmez a bilaterality is present even in the very tiny ovarian egg.

On this view it is, of course, necessary for consistency, to suppose that at the time when the egg breaks out of the follicle to be swallowed by the enveloping infundibular funnel, one of its ends enters first, as stated above, and the method of breaking of

[1] Something more than bilaterality is required to explain why the right side rather than the left should be the first to enter the oviduct.

the stigma is supposed to be of such a kind as to bring this about, or else the materials of the ends must be supposed to be of such a sort that one end is more likely to enter than the other. Floating ovarian eggs, freed from the follicle, give evidence, Bartelmez thinks, that there is a difference in the specific gravity of the two ends in question. His account is so detailed and positive that it might appear to settle the question for the bird's egg; but on the other hand, it may be pointed out that the evidence relating to the very young eggs is by no means as certain as the importance of the situation demands. It is, moreover, difficult to obtain accurate evidence of this kind. The considerable variation in the position of the embryo with regard to the long axis of the egg on which the author lays such emphasis indicates either that the early bilaterality of the egg bears a very variable position to the axis of the embryo, or else that there is much variation in the way the egg enters the oviduct and passes down its length, which is not in full harmony with the interpretation of the process as described as taking place. In the rare cases where the head of the embryo is turned in the reverse direction Bartelmez assumes that the wrong side of the egg has, perchance, entered the oviduct first.

The axes of the chick embryo are already determined in the oviduct before the shell is laid down, since gastrulation takes place in the oviduct. The pressure of the oviduct on the two ends of the egg that determines the shape of the albumen would give, theoretically, an explanation of one of the factors involved, namely, the position of the embryo across the long axis of the egg. It remains still to be shown why the head of the embryo lies on a specific side of the yolk. The following suggestion may furnish a clue. If the position taken by the egg on entering the oviduct is due to differences in compressibility of the egg of such a sort that it is more easily compressed in its primary axis (due to the distribution of the concentric rings of yolk); and if the advancing and the following ends of the egg are under somewhat different conditions (due to the contraction behind and the relaxation of the tube in front that allows the egg to advance); and if the spiral path taken by the egg in its passage down the tube is due to the structure of the oviduct; and if the spiral is, as a rule, a right- (or left-) handed spiral (as shown by the albumen), then the conditions are such that one side of the blastodisc is subjected to different influences from the opposite side. If this affects the position of the embryo, either directly or indirectly, in somewhat the same way as the bilateral antero-posterior shape of the egg-case in many insects may be supposed to determine the orientation of the embryo, there is a formal explanation of the orientation of the chick. Further observations are needed to settle the truth or falsity of this hypothesis.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

SCIENCE AND PSEUDO-SCIENCE

MODERN complex industrial life plunges every one into a scientific environment so that no one can escape the deluge of scientific terms. But he may get them wrong. Each new discovery starts a parasitic growth of pseudo-science.

There *is* a north pole; but Cook didn't discover it.

There *is* magnetism; but not "animal magnetism."

There *is* wireless telegraphy; but that does not prove telepathy.

There *are* electrons; but "electronic" cures do not follow.

From miscellaneous reading in the papers the average layman gets a confused, composite, half-digested impression to the effect that "Science says":

People are descended from "monkeys"; the sun is made of radium; Mars is inhabited by a race of canal diggers; the ancient Mayas knew all about relativity; the earth is getting hotter; the earth is getting colder; the earth will be smashed up by running into a comet; the average mental age of Americans is thirteen; all progress comes from a superior Nordic race; mankind is losing all its teeth and hair; the world is going to starve to death from overpopulation; the world is going to die off from race suicide; Conan Doyle proved the existence of fairies; drinking sour milk or grafting goat glands will make everybody live to 150; there is no soul; everybody has two or three souls; according to Freud you must give rein to every impulse or die of a complex; all rheumatism comes from bad teeth; all diseases can be cured by manipulating the backbone; harnessing the power of the tides will replace coal as a source of power, etc., etc.

Some of these notions are false, some are hypotheses which may or may not be true, some are truths badly expressed or placed in a misleading context. The result is that the layman either becomes sceptical of all science or credulously falls victim to the first faker that can manipulate imposing catchwords.

Not only do new superstitions crop up from the soil fertilized by genuine discovery, but the old weeds still linger. Dream books, not only those based on Freud, but others of the old traditional sort, still sell in the shops. Fortune tellers manipulate packs of cards as well as Ouija boards. Astrology numbers more followers than lived in Egypt, Chaldea and Rome. We are only two hundred years removed from witch-burning forefathers, and some would do it yet if the law permitted. An excited fundamentalist in a Southern paper demands that all evolutionists be crucified head down.

This is not all cause for pessimism. At least it shows that science attracts great interest and has vast prestige. "Imitation is the sincerest form of flattery." If fifty years ago legislatures did not persecute Darwinism it is because the average legislator had never heard of it. If people talk nonsense about Freudianism, hypnotism, Einstein, psychological tests, vitamins and the like, at least they have heard of these things and want to

—*Wide World Photos*

MADAME CURIE

The twenty-fifth anniversary of the discovery of radium by Pierre Curie and Madame Curie has been celebrated at Paris with suitable ceremonies. The French Chamber of Deputies has voted a special pension to Madame Curie and to her children.

—*Wide World Photos*

DR. ROBERT ANDREWS MILLIKAN

Director of the Norman Bridge Laboratory of Physics and chairman of the Administrative Council of the California Institute of Technology, to whom the Nobel Prize in physics has been awarded.

hear more about them. All they need is some clue as to what things are so and what things are not.

Unfortunately those who trade on the name of science for profit, or who are fanatically sincere about some absurd theory, are better advertisers than the real scientists. They make more noise, assert themselves more dogmatically, make more sweeping claims and get attention first. They are not handicapped by the hesitations, uncertainties, shyness, professional caution of the true man of science. Reservations and qualifications make dull reading, and the necessary complexities of the scientific vocabulary frighten away the casual reader. Moreover, it is to be feared that some scientists are intellectual snobs and do not care whether the layman understands or not. They leave the field to pseudo-science without a struggle.

On the other hand, in the long run real science prevails over what the Bible terms "science falsely so-called" because it can prove itself by its works. "By their fruits ye shall know them," the experimental method. Only real chemistry can provide the basis for the big industrial inventions which the public demands and appreciates. Only real medicine can in the long run lower the municipal death rate.

There is another test of real science; its honesty. Fake science always tries to create mystery, to use long words for the purpose of creating confusion, to rely on occult forces and secret processes, because only so can it remain a profitable monopoly. Real science relies on tests and experiments that any one can duplicate and does not add artificial difficulties to the real mysteries of nature. In a word, the real scientist and the faker are both talking to the layman in unknown tongues, but the real scientist is trying to make himself understood, the faker is trying to make himself misunderstood.

HOW WOMEN CONTROL THE FUTURE

Woman's sphere has become greatly enlarged in recent years. It is considerably larger than it used to be and vastly larger than it used to be thought. I do not allude to the political enfranchisement of women—this was merely an act of justice and will doubtless prove beneficial, but it is insignificant in comparison with what I have in mind, that is, woman's power over the rising generation through her share in inheritance and her control of early training.

There are two kinds of inheritance, the internal and the external:

First, the physical inheritance, the constitutional transmission of bodily and mental characteristics and capabilities.

Second, the cultural inheritance, by which language, institutions and laws, science, art and ethics, are handed down from one generation to the next, and the training by which character is molded and set.

Now in the first, the bodily heredity, women have an equal part. They have always had it, of course, but this was not known until demonstrated in recent laboratory experiments. It was formerly thought the masculine element predominated in heredity; that the law of primogeniture held in the physiological as in the legal world; that traits are handed down with the father's name. Genealogists traced up the line of names and since the mother's name was dropped her hereditary bequest was supposed to be slight and soon eliminated. But the Salic law does not hold in nature. Modern science has revealed two facts in regard to heredity that put the

PROFESSOR A. V. HILL

Appointed to the Jodrell Chair of Physiology in the University of London this year, and joint winner with Professor Meyerhof, of Kiel, of the Nobel Prize in physiology. From a pencil drawing, from life, by F. W. Schmidt, Manchester.

position of woman in quite a new light. First, that the mother's share is exactly the same as the father's in the transmission of characteristics to their offspring, and, second, that such inheritance is vastly more important than we formerly supposed. In short, that nature is more powerful than nurture, and that a person's capabilities are strictly limited and largely determined by his endowment at birth.

This equal share in fixing the character of the coming generation is settled upon woman by the Creator and she can not alter or escape it except by evading maternal duties altogether. Nor can she improve upon her present practice except by exercising greater care in the selection of a husband, and there she is limited by having such a poor lot to choose from.

It is otherwise in regard to the second kind of inheritance, the external or cultural. Here woman's part has become recognized as larger and has become actually enlarged. Women have always had the care of children from infancy mostly in their hands, either as mothers, nurses or kindergartners. This task was left to the women because it was bothersome and was not thought to amount to much. If the children got the proper amount of calories and vitamins and had their muscles exercised at proper intervals, nothing else mattered much. We can all remember when certain reformers advocated putting babies in big orphan asylums where they could be cared for by wholesale and presumably more efficiently. But now we know better, for modern psychology has shown that our morals and temperaments are largely molded by the influences of infancy, that the fears and the affections of the nursery may haunt one through life, that cradle songs and childish jokes may make or mar a man's career. It has long been recognized that in religious training the first seven years of life are the most important.

If you have watched the making of a concrete building you know that there are two critical points in the process:

First, the composition of the concrete, the quality of the ingredients and how they are mixed.

Second, the settling of the concrete, how it is poured, compacted and distributed and settled. The first hour after pouring determines once for all how well the building will stand. Afterwards nothing can be done to improve the mass of concrete except to chip it into shape and give it a superficial polish and tint.

So it is with human beings. The two things that most determine character and destiny are natural endowment and childhood training. Now women control 50 per cent. of the natural endowment and some 75 per cent. of the childhood training. More than that, they have, through taking up the teaching profession, gained control of most of the formal education of both boys and girls up to the age of adolescence. At seventeen years in most cases, and often earlier, one has all the native intelligence he ever can have and what he learns later is how to use it. His character is by this time so solidly set that neither he nor any one else can do much to change it.

So through natural endowment and modern custom women have come to have control of a majority of the formative influences of successive generations, some 60 to 70 per cent., depending on how you count the earlier character-forming years. Even in that form of cultural heredity where the chromosomes are words, that is, literature, women are taking an increasing part, for they now write a large proportion of our books and periodicals.

ASTRONOMICAL EVENTS IN 1924

BY ISABEL M. LEWIS

THE closest approach of Mars to the earth in at least a generation; a transit of Mercury across the sun's face, an event which will be repeated but three times this century; five eclipses; and occultations of Mercury, Neptune, Aldebaran and Regulus by the moon, are the leading special offerings of the heavens to star gazers in 1924. Three of the eclipses will be of the sun and two of the moon, but none of them will be visible in the United States.

By far the most interesting astronomical event of 1924 will be the near opposition of Mars next August. Every fifteen or seventeen years the opposition of Mars occurs when the planet is not far from perihelion or the point in its orbit nearest to the sun. The planet is then about 26,000,000 miles nearer to the earth than it is at its most distant opposition, which occurs when it is near aphelion or the point in its orbit farthest from the sun. The last close opposition of Mars occurred in September, 1909, when Mars came within 36,180,000 miles of the earth. On August 22 of this year, a few hours before it comes into opposition with the sun, Mars will be at a distance of 34,630,000 miles from the earth, which is very nearly, if not quite, as close as it can ever come to the earth, and about one and a half million miles nearer than it was fifteen years ago.

The coming opposition of Mars is being awaited with keen interest by all interested in the study of the surface markings of this sister world, which, next to the moon and Venus and an occasional asteroid or comet, comes nearer to us than any other member of the solar system.

Schiaparelli made his much-debated discovery of the "canals" of Mars at a close opposition, that of 1877, which he confirmed at the following favorable oppositions of 1879 and 1881. Every close opposition of this mysterious planet brings additional observations of special interest and value and it is practically certain that this, the closest of all, will be no exception.

Mercury will cross the face of the sun on May 7, the transit taking about eight hours from ingress at the eastern edge to egress at the western edge of the sun. In the United States only the ingress of the planet will be visible, the sun setting with Mercury on its disk. The entire transit will take place above the horizon in Alaska and the Philippines. The last transit of Mercury took place on November 6, 1914, and future transits will occur on November 12, 1940, May 9, 1970, and November 14, 1999.

The solar eclipses of 1924 will all be partial and the lunar eclipses will be total. The partial solar eclipse of March 5 will have a greatest magnitude of 58 per cent., and will be visible only in the Antarctic and South Atlantic oceans and the extreme southern part of Africa. The solar eclipse of July 31 will have a magnitude of 19 per cent., and will be visible only in south polar regions. The solar eclipse of August 29 with a greatest magnitude of 43 per cent. will be visible in the Arctic Ocean, Greenland, the northern part of Norway and Sweden, northern Russia, Siberia, northern China, Kamchatka and Japan.

The total eclipse of the moon of February 20 will be visible in the extreme northwestern part of North America, the Pacific Ocean, Australia, Asia, the Indian Ocean, Europe and Africa, except the extreme northwestern part.

The total eclipse of the moon of August 14 will be visible in the western part of the Pacific Ocean, Australia, Asia, the Indian Ocean, Europe, Africa, the Atlantic Ocean, and eastern and central South America.

Occultations of Aldebaran by the moon, visible in the United States, will occur on February 13, April 8, June 28 and September 18. The first-magnitude star Regulus, in Leo, will also be occulted on October 22, the planet Mercury on August 2 and Neptune on November 18. As Neptune is not visible to the naked eye its occultation by the moon can only be viewed telescopically.

THE SERVICE OF SCIENCE

"EVOLUTION can not be killed by legislative enactment," declared the retiring president of the American Association for the Advancement of Science, Professor J. Playfair McMurrich, of the University of Toronto, in a notable address which opened on December 27 the program of the seven day meeting of the association at Cincinnati. Professor McMurrich reviewed the progress in scientific thought in the seventy-five years since the association was founded and stated that the doctrine of evolution was the guiding clue through the flood of new knowledge, the stimulating idea without which much of scientific progress would never have been conceived. Doubts of its validity could only be based on ignorance or prejudice. Professor McMurrich continued:

> In the popular mind the doctrine of evolution is so completely involved in Darwin's exposition of it that it has come to be regarded as the product of his brain. Consequently any acknowledgment that some of Darwin's views may require modification is assumed to imply that the foundations of evolution are shaken. It seems trite to repeat once more the true relation of Darwin's theory to the doctrine of evolution, but there seems to be need for its repetition.
>
> Evolution as a theory long antedates Darwin's time; Laplace, to go on farther back, found it in the history of the heavenly bodies Lyell demonstrated it in the history of the Earth, and Goethe, Buffon and Lamarck saw it in the history of terrestrial organisms. What Darwin did was to give a plausible and convincing explanation of how organic evolution might have occurred, but whether that explanation is or is not the correct one matters not so far as the doctrine of evolution is concerned; that stands unshaken even though Darwin's explanation of how it was brought about be discarded. The evidence in its favor to-day is many times stronger than it was in Darwin's time and it seems incredible that man as a reasoning animal should presume to doubt its validity.

The retiring president urged upon the association the duty of putting the results of researches into popular language for the benefit of those who have not had scientific training. He said:

> These form a not inconsiderable and important portion of our membership, they come to our meetings to hear something of the latest achievements of science and they listen to addresses largely in an unknown tongue. They ask for bread and are given a stone and profit little from such a monolithic repast. Yet these are the persons that we should endeavor to interest if we are truly and fully pledged to promote the advancement of science. Esoteric science may lead from discovery to discovery, but until the significance of its discoveries is made intelligible to what are termed the men in the street it fails to secure popular support. The unintelligible is mysterious, and mystery awakens either ridicule or dread.
>
> Much has been spoken and written concerning the need for a popularization of science and something has been done towards its accomplishment, notably the establishment of Science Service so ably edited by Dr. Slosson. But is not this very thing a prime duty of this association, devoted as it is to the advancement of science, and does the association live up to the full measure of its responsibilities in this matter?

Revolutionary changes in popular beliefs brought about by science are now looked upon without alarm, and this altered attitude was, in the opinion of the speaker, due to the many practical applications of science.

The distrust of seventy years ago has given way to trust and the world accepts with tranquility the shattering of many old beliefs, providing that the necessity for their destruction is vouched for by competent scientific opinion. The theory of relativity, whether or not its full significance is understood, is swallowed without a spasm, even though it may displace the theory of gravitation from what seemed to be its unassailable position; and that the atom, supposed to be the ultimate, indivisible abstraction of human thought, is in reality a more or less complex system of electrons revolving planet-like about a central nucleus, even this idea is accepted without a tremor.

This change of attitude is undoubtedly largely due to an increased appreciation of the value of science as shown by its practical applications. This may not have been the only factor, but it is a potent one. It is impossible to consider the multitudinous and marvellous facilities that have become parts of our daily life without realizing that they are but the practical applications of scientific principles to the control or utilization of natural forces and materials, without, in other words, perceiving that it is to scientific investigation that we are indebted for these advantages. The men who have made these practical applications become known and respected, their names become household words, they are the representatives and high-priests of science and their glory is reflected upon even the most abstruse fields of scientific investigation. The attitude assumed may be expressed thus: "See what great benefits science has conferred! It promises others and therefore it is to be encouraged."

For the present we must perhaps be satisfied with this. For several centuries science was under the ban, dogma was supreme and science, which necessarily found itself in contest with this, was impious and heretical. Truth was standardized and complete and to question that accepted truth was to undermine the foundations of belief. The human mind is conservative in its reactions; habits of thought are as difficult of modification as habits of action and the change from the dogmatic to the scientific habit has been slow; indeed, it is far from complete even now. The utilitarian appeal of science has done much to emancipate it from the thraldom to dogma, but it is not yet universally recognized that the utility of science depends absolutely upon its success in discovering truth. It is only by getting at the true facts and the true principles involved in any problem that the results of science become useful. The scientist is a searcher after truth and it is for that reason that he is able to confer benefits on humanity; it is for that reason that he deserves recognition. Surely he should feel no necessity for an apology for his existence.

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THE ORIGIN, NATURE AND INFLUENCE OF RELATIVITY[1]

By Professor GEORGE D. BIRKHOFF

HARVARD UNIVERSITY

I. Euclid, Newton, Faraday and Einstein

A very simple and precise aspect of experience is that of the spatio-temporal relation between material objects. The underlying concepts of space and time have deeply influenced physical, astronomical, philosophical and even religious thought. A broad understanding of them appears to be indispensable for an adequate appreciation of the universe in which we live. The historical development of these concepts, culminating in the theory of relativity of Einstein, throws much light upon their nature. Perhaps the names of Euclid, Newton, Faraday and Einstein, more than any others, are representative of the various stages in the evolution which has taken place.

The significance of number, time and space must have been felt in the earliest period when man's mental power was comparable to that which he possesses to-day. Elementary facts about unity and multiplicity, succession in time, size and shape, are presented at every turn by experience. They have a curious inevitability and completeness, characteristic of mathematical truth, which was certainly perceived in this period. For example, the fact that there are two chief luminaries, the sun and moon, that they function in alternation, and that they resemble each other in size and shape must have stirred human interest even then. Doubtless the nascent elements of various fields of science were known to primitive man. The ability to handle material objects involved a perception of some principles of mechanics; experience in dealing with hot and cold bodies led to a familiarity with properties of heat; and the neces-

[1] Lowell lectures.

sary requirement of taking account of day and night, and of the seasons, brought about a grasp of a little elementary astronomy.

The systematization of the process of counting was the first great step towards that understanding of and control over nature which is characteristic of our day. At first there was only the process of counting by means of the fingers, stones or other objects. Then came the naming of the numbers, as one, two, three, etc., skill in reckoning with them, and their use in commercial pursuits, the measurement of land, and astronomy. Nearly two thousand years before our era the Egyptians were very competent in the use of number. The priesthood of that time had the leisure and interest for occupying themselves with scientific thought. A mathematical papyrus written by a scribe Ahmes, entitled "Directions for obtaining the knowledge of all dark things," witnesses to their arithmetic proficiency.

In their surveying, artistic designing and astronomy the Egyptians became adept in geometrical construction and must have

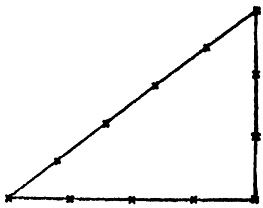

FIG. 1

been familiar with many truths of geometry. The right triangle with sides of three, four and five units was probably known to them and used in surveying. A floor in tiles with the pattern below indicated to the eye that the square on the longest side of a right triangle with two equal sides has an area precisely equal to the sum of

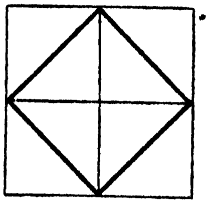

FIG. 2

the two areas of the squares on the equal sides. Moreover, practical urgency as well as merest curiosity led them to estimate with considerable accuracy the ratio of the distance around a circle to its distance through. The inscribed hexagon showed at once that the ratio exceeded three. Since that day long ago geometrical knowl-

edge has advanced very far and this ratio has been fully determined; it is exactly four fold as great as the number obtained when 1 is diminished by 1/3, then increased by 1/5, diminished by 1/7, and so on *ad infinitum.*

It may not be amiss to note in passing that not all elementary geometrical conundrums have yet been answered by professional mathematicians. Thus, map-makers have noted that apparently any imaginable map on the plane or sphere can be colored in only four colors in such wise that two countries with a common boundary

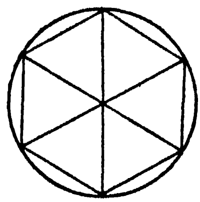

FIG. 3

line have different colors. Despite persistent efforts, the truth of this conjecture has not yet been established, although five colors are known to be enough. Of like intriguing simplicity is the question raised a few years ago by the Japanese mathematician Kakeya as to the least area within which a line of given length can be turned around in a plane. An area half as great as that of the circle with

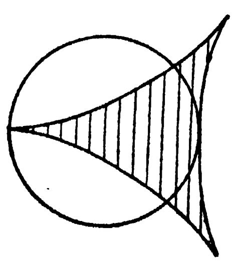

FIG. 4

this length for diameter will suffice. No one has as yet been able to prove that this is the least possible area.

Since all physical science depends upon the foundation of mathematical truth, of which the discovery has been hastened by intellectual curiosity, a high place can be granted such curiosity for its proved value to mankind.

No advance in the logical analysis of geometrical relations was achieved by the Egyptians. As soon as their empirical geometry had passed to Greece through the Greek geometer Thales about 600 B.C., it began to be transformed by Greek ability and interest

in abstract speculation. The great although obscure figure of Pythagoras has unusual importance for the early Greek period. The relation between the sides of a right triangle, illustrated in the triangle of sides three, four and five units, was probably discovered in its full generality by him. He found the two remaining regular solids of twelve and twenty sides, of which the Egyptians had known the other three. To him is attributed the determination of the relation between the length of a musical string and its pitch, exemplified in a simple way by the fact that if its length is halved, the note is raised exactly an octave. For Pythagoras these truths indicated a deep and mystical interdependence between number and nature. Number was taken by him to be at the root of everything, and its properties formed the foundation of his philosophy. Thus the regular solids represented elements in nature; the seven planets were held to give out musical notes proportionate to their distances from the sun, forming the music of the spheres.

Euclid, who lived a couple of centuries later, was the great systematizer of Greek geometry. His feeling for the purely logical side of geometry was uncanny in its accuracy, despite the fact that from the modern point of view the "Elements" are by no means free from blemishes. It was his achievement to have shown how all the known truths of geometry follow necessarily from a very small array of almost undeniable propositions called axioms and postulates. He was not primarily a discoverer of new geometric truths.

What interests us here is not so much the precise body of doctrine concerning points, straight lines, angles, circles, lengths, areas, etc., which he developed, as his point of view toward its application in the physical world.

In fact there are two alternative points of view towards geometric doctrine which can be held. One (that of Euclid) holds that we are dealing with a system of rigid bodies of fixed size and shape, of which material objects like tables, blackboards, rulers, the earth, etc., are fairly satisfactory embodiments. By handling these bodies and comparing them with one another, we arrive at the truths of geometry. For example, when it is affirmed that two points determine one and only one straight line, this may be taken to mean that if we fix upon two points A and B of a rigid body, then when the simple kind of rigid body called a straight line, and exemplified by any ruler, is placed upon the rigid body so as to contain the points A and B, the line will always be found to contain the same points of the rigid body, forming the straight line AB of the body.

It is entirely compatible with this interpretation that any rigid body can be indefinitely extended into a "space." Thus a man in

a moving railway train may estimate that a boulder directly opposite his window is 100 feet away and thus obtain its instantaneous position in the space attached to the train. The boulder also occupies a definite position in the space attached to the earth. Either of these spaces is in motion relative to the other.

The other point of view holds that there is a particular rigid body for which extension into a space is peculiarly proper, which space may then be called "absolute space"—a kind of omnipresent, penetrable, rigid body. Any material body fills a definite part of absolute space at any instant. With this interpretation the fact stated about straight lines means only that for a given pair of distinct points A and B of this space there is one and only one set of its points of the type called a straight line and containing these two points.

It was undoubtedly the second point of view that was generally held by the Greeks. Thus the point was a monad having position for the Pythagoreans. The conception of the point as that which is indivisible and has position was maintained also by Aristotle. Those who hold to the second point of view must contend with Aristotle that the principle of superposition has no place in geometry as a first principle, since two bodies may be superposed if and only if they occupy equal spaces.

On the contrary, Euclid himself, with that marvelous instinct for the essential which is characteristic of his work, defines the point as that which has no part, *i.e.*, as the indivisible rigid body, and does not require that it have position in some hypothetical absolute space. This fact and the use which he makes of superposition as a fundamental principle indicates that he preferred not to employ the concept of absolute space.

It is necessary to have the divergence clearly in mind.

Euclid saw that the science of geometry as applied in nature attaches no particular importance to any special reference body. Thus for him a point was merely a small identifiable rigid body. Rigid bodies were to be compared by superposition, and it did not make any difference just how the superposition was effected in any particular case. Consequently, to insist that any particular body defined an absolute space was unnecessary. It seems, then, that Euclid adopted a relativistic point of view toward space.

On the other hand Aristotle saw that in every-day experience a particular reference body, namely, the earth, played a preponderating rôle. It must have appeared to him that other rigid bodies were entirely unsuitable as reference bodies. Despite the fact that from a purely logical standpoint all rigid bodies stand on a parity in the geometry of Euclid, some such vague considerations, not essentially geometrical but rather mechanical in their nature, in-

clined Aristotle to maintain the concept of an absolute space attached to the earth.

The opinion to be presented here is that if some particular reference body has a superiority for the elucidation of nature, then it is desirable to signalize the fact by giving a special name to the space attached to the body. It is undesirable to pay any veneration to that space, since the fact is thereby obscured that, from the standpoint of geometry in itself, all rigid bodies are on an equal footing.

There is, then, a relativity present in the application of the geometry of Euclid to nature which allows us to start from any particular rigid body of reference, as defining a space of its own, and then to locate the position of other bodies at any time relative to that space. The relativity found here may be called *geometrical relativity.*

Before leaving the consideration of the Greek period, it is desirable to summarize the application of geometry in astronomical theory, for here the concept of time enters to join that of space, thus furnishing a very good vehicle for the statement and comprehension of the observed facts.

As might be expected, light was thought of by the ancients as instantaneous. Nearly two thousand years elapsed before it was discovered that light travels at the rate of nearly 200,000 miles a second. Consequently, events were correlated everywhere as happening when they were seen, this being done for events observed in the heavens as well as on the earth. Without any analysis of the notion of absolute time implicitly involved, a particular reference body and its absolute space was taken, to which the position of other bodies was then referred at any instant of absolute time. The explanation of astronomical phenomena was sought on the basis of this structure of space and time.

The application of geometry led very early to the recognition of the fact that the earth was a sphere. While traveling in Egypt Pythagoras became acquainted with this opinion. He seemed to have promulgated secretly the heliocentric theory, which gave the sun a central place. However, the dominant opinion of the Greek period held the earth to be absolutely at rest, *i.e.*, the venerated reference body. The great observing astronomers of near the beginning of our era, Hipparchus and Ptolemy, chose this theory. Ptolemy held any other theory to be ridiculous, despite the fact that he recognized the superior simplicity of the heliocentric theory for some purposes. While the geocentric theory, in which the earth defined the absolute space, had the advantage that observations were made in that space, it had the extreme disadvantage that the description of the motions of the sun, moon and planets became

very complicated. The concept of multiple epicyclic motion was invented to account for the facts in geocentric terms. In truth, to explain the motion of a planet on this basis, it was necessary to take account successively of rotations in three distinct spaces.

In the sixteenth century of our era, Copernicus selected the sun (taken as not rotating in the frame of the fixed stars) as defining the reference space. The theory of Copernicus found only slow acceptance. From our point of view the real significance of his theory is that the explanation of the astronomical facts is in this way made very much more simple. No doubt the Copernican theory would have been accepted at once by Euclid, for none would be more ready than he to grant that the new theory was accommodated to pure geometry fully as well as the Ptolemaic theory.

In the seventeenth century Kepler and others, under the stimulating simplicity introduced by the Copernican ideas, were able to understand and follow the motions of the moon and planets far more accurately than had been done before. There arose the belief that the same gravitational force which pulled terrestrial bodies to the earth was also operative between bodies at great distances apart, and controlled the solar system. However, the mathematical means for investigating the truth of this conjecture had not yet been invented.

The discovery of analytic geometry by Descartes in the first half of the seventeenth century was a first necessary step in this direction; the Pythagorean vision that all was number was thereby justified in the field of geometry. It is the achievement of Newton to have invented the infinitesimal calculus, which deals with varying quantities, and to have applied it to the problems of the solar system. A brilliant result was his law of universal gravitation.

The dogmatic adherence of Newton to the doctrines of absolute space and time is sufficiently apparent from the first scholium of his "Principia." A translation of a few characteristic passages will show with what seriousness he subscribed to these doctrines:

I. Absolute, true and mathematical time, of itself, and from its own nature flows equably without regard to anything external, and by another name is called duration; relative, apparent and common time is some sensible and external (whether accurate or unequable) measure of duration by means of motion. . . .

II. Absolute space, in its own nature, without regard to anything external, remains always similar and immovable. Relative space is some movable dimension or measure of the absolute space. . . .

III. Place is a part of space which a body takes up, and is according to the space, either absolute or relative.

IV. Absolute motion is the translation of a body from one absolute place into another; and relative motion, the translation from one relative place into another.

Of course Newton endeavored to justify his unqualified adher-

ence to these doctrines. In fairness to him it must be said that he succeeded partially in doing so in the following manner. Imagine a dumb-bell tossed into empty space at such a distance from any other bodies that gravitational forces need not be considered. On the basis of Newton's laws of motion, it follows that there will be a tendency of the weighted ends to separate if there is any rotation, whereas if there is no such rotation, there will be no such tendency. Thus, "absolute rotation" can be detected by means of the slight elongation of the bar joining the weights. Hence, there are mechanical methods for ascertaining absolute rotation. Direct experiment indicates that such rotation is merely rotation with reference to the so-called fixed stars.

The case of motion in a straight line with unvarying velocity stands on an entirely different basis in Newton's theory. There is given no principle by which such uniform rectilinear motion of an undisturbed body in empty space can be ascertained, and it is inherent in his entire system of thought that this is so. Newton himself realized the situation more or less vaguely for he says in the same scholium: "It is indeed a matter of great difficulty to discover, and effectively to distinguish, the true motions of particular bodies from the apparent; because the parts of that immovable space in which those motions are performed, do by no means come under the observation of our senses. Yet the thing is not altogether desperate. . . ."

For example, on the basis of Newton's theory the sun is an undisturbed body, at least if the minor disturbing gravitational forces of the planets and other heavenly bodies are ignored. According to his theory, it may be either at rest in his absolute space, or describing a straight line in that space with constant velocity. His formulation of mechanical principles is such, however, that if the motion of all the heavenly bodies be computed on the hypothesis that the sun is at rest, *i.e.*, using the space attached to the sun, the result predicted will be exactly the same as if the space of any other star than the sun is taken to be at rest.

The advance of the Newtonian over the Euclidean point of view can be stated in dispassionate terms as follows. Newton accepts the truths of geometry, according to which there are as many spaces as there are real or ideal rigid bodies, and yet he notes that some spaces are more suitable than others for describing natural phenomena, namely, the spaces attached to rigid bodies moving freely in empty space and in such wise as to be subject to no tendency of their parts to separate. It is only with respect to such a space that his first law of motion holds: "Every body perseveres in its state of rest, or of uniform motion in a right line, unless it is compelled to change that state by forces impressed thereon."

His doctrine of absolute space insists unnecessarily that one such space is supremely important, and accordingly to be termed "absolute." But the fact is that all his laws of motion are expressed in identically the same way whatever such space is employed. An illustration of the truth of this fact is afforded by the behavior of a ball in the space of an elevator which is descending at a constant velocity. It will be found that the ball falls in this space exactly as though the elevator were at rest.

Newton's corpuscular theory of light and his law of gravitation have this characteristic property of relativity.

If the space of a rotating body is selected, any freely moving body describes a complicated spiraliform curve in it. Thus the choice of Newton of reference spaces attached to a special type of freely moving body, namely, any one not in absolute rotation, is justified by the test of simplicity. There is no justification for the selection of a special one of the possible reference bodies of this type as against all others.

Consequently, on the basis of the Newtonian theory a *mechanical relativity* holds sway which is not as inclusive as the geometrical relativity signalized earlier, but which fails nevertheless to distinguish between the spaces of various bodies in uniform translational motion relative to one another.

The success of the heliocentric theory turns upon the fact that the sun is far more nearly an undisturbed body in such uniform motion than the earth, moon, or planets. But the space used can not rotate with the sun and so is of the Copernican type; otherwise the stars would travel in circular orbits in the space, contrary to the first law of motion. The real motive for the use of the heliocentric system is now reduced to its proper basis, namely, that with this type of reference body the motions observed can be described with maximum simplicity.

Undoubtedly Aristotle had a vague feeling for the fact that when mechanical ideas are admitted there is less relativity allowable than when only purely geometric considerations are taken into account. This is especially apparent when he classifies motions as being according to nature and contrary to nature. However, he made no analysis of the reasons for his choice of the earth as a uniquely determined reference body, and indeed could not have been expected to do so.

The full validation of the concepts of absolute space and time seemed to be at hand when the rôle of electricity and magnetism in nature began to be discovered. These phenomena were the latest to impress the attention of physicists, so that even magnetism was scarcely mentioned by Newton.

The name of Faraday stands foremost among those who have

investigated the facts concerned. To him is due the first complete statement of the interrelation between electrical and magnetic phenomena. He was the only one of the four men towards whom we are directing especial attention who was not a working mathematician. He lamented his lack greatly. It required his mathematical interpreter Maxwell to give Faraday's concretely expressed "lines of force" an exact and adequate statement. As Maxwell says of Faraday in the preface of his "Electricity and Magnetism":

> Faraday, in his mind's eye, saw lines of force traversing all space where the mathematicians saw centers of force attracting at a distance: Faraday saw a medium where they saw nothing but distance: Faraday sought the seat of the phenomena in real actions going on in the medium, they were satisfied that they had found it in a power of action at a distance impressed on the electric fluids.

When Maxwell had succeeded in giving the concepts of Faraday satisfactory mathematical formulation, he found that it followed also that the electromagnetic wave, such as is sent out from any wireless station to-day, travels of necessity with one and the same velocity under all circumstances in empty space, and that this velocity is given as the ratio of two well-known units in electricity and magnetism. Of course, the velocity is relative to the medium imagined by Faraday, called the ether and conceived as a particular one of the Newtonian spaces, namely, the one which Newton signalized as "absolute." Maxwell found that this calculated velocity was the same as the known velocity of light. Thence he derived the epoch-making conclusion that the light wave is electromagnetic, *i.e.*, the same in type as the wireless wave. All subsequent investigations have verified the truth of this conjecture and also the adequacy of his mathematical equations for expressing the facts of light and electromagnetism. Faraday had conjectured a relation between light and electricity. Maxwell demonstrated it in all detail.

At last the absolute space of the Newtonian philosophy, which had provoked numerous questionings since it seemed without substance, began to have definite properties. At last there appeared to be a basis of distinction between the various mechanically equivalent spaces of Newton by means of the electromagnetic ether. Thus in turn the geometrical concepts of Euclid, the mechanical concepts of Newton and the concepts of electric and magnetic interaction of Faraday narrowed the possibilities down so that all spatial relativity was apparently excluded. There were many who conceived that the main laws of the physical world had been formulated, and that nothing further remained than to ascertain the precise way in which atomic matter and electricity were joined together in the atom.

As in any genuine theory this view of nature was left open to verification. It became possible to determine absolute motion through the ether by experiment, and so discover absolute space. The fundamental method suggested for this ultimate quest can be explained as follows: If a man swims up-stream a given distance and back, he will find that it takes him more time to do so than if the water is at rest. This is particularly apparent in case he makes only slight headway against the stream. It is assumed that his velocity through the water is the same in both cases. Now a rigid body in motion through the ether may be compared to the banks of the stream, the ether to the stream which is moving past the body, and a beam of light which is flashed from a point of the rigid body to a second point at a given distance from the first and reflected back again, to the swimmer. It ought to take more time for the beam to travel back and forth along a bar in uniform motion in the ether than if the bar is at rest.

Owing to the variable character of the earth's motion, it was found possible to devise apparatus by which this increase of time should be revealed by a shift in position of certain interference fringes. As carefully tested in this way by Michelson and Morley in 1887, the earth showed not the slightest trace of motion relative to the ether. The attempt to explain the negative result by means of the hypothesis of a "drift" of the ether with the earth was meaningless, since the ether was by hypothesis a particular one of the Newtonian spaces, and the equations of Maxwell called for one and the same velocity of propagation of light in empty space of this sort under all circumstances. Such a suggestion of ether drift must remain incomprehensible until some modification of the foundations of physical theory is made. No one has proposed a definite and consistent modification of this kind.

A variety of subsequent experiments confirmed the general conclusion that the earth was entirely indifferent to motion relative to the ether. Nature unexpectedly refused to yield up the long held secret of an absolute space at the very moment when all were of the opinion that it was to be wrested from her.

The perplexity into which physicists were thrown by the situation was much more embarrassing than appeared at first sight. Absolute space was intangible, and it began to appear that absolute time was not much less so. If the synchronizing of clocks at different places on the earth's surface is to be effected accurately, a method of light signaling must naturally be employed. Without a knowledge of the velocity of the earth in the ether it is not possible to allow exactly for the time required by the signaling process. In fact the natural way of synchronizing such clocks appeared to be

to assume the earth at rest in the ether, because of the absence of any effect; and this was out of the question inasmuch as then the timing would not be absolute but only relative to the earth.

The notion of absolute time has been taken without the slightest analysis in the historical sketch attempted above. It is necessary now to begin to consider ideas of time as well as of space, and hence it must be pointed out what a sweeping hypothesis is involved in the notion of absolute time. Suppose that I snap my fingers. Events happen throughout the universe which I propose to bundle together as having happened at the same instant. The method which I use to determine the events happening at the instant must be physically unique and not arbitrary in the least degree. If the physical means adopted of finding these events has any uncertainty in it, the measurement of distances will share in the uncertainty, since the position of a body at one instant of time will be compared with the position of a second body at a different instant.

At first thought it might occur to me to correlate events as happening when I see them, for this is the method of ordinary experience. If I did that, however, I would consider a change in the light from a distant star to take place when it becomes visible through the telescope, contrary to all astronomical procedure.

For these reasons it is clear that the notion of absolute time involves a definite hypothesis concerning the physical structure of the universe.

A variety of physicists and mathematicians, among whom Fitzgerald, Lorentz and Henri Poincaré are particularly to be mentioned, speculated upon the difficulty, without avoiding the unnecessary hypothesis.

In 1904 Lorentz arrived at a kind of solution of the problem, which it is most instructive to consider. He assumed that the very circumstance of motion relative to the ether caused a moving body to contract in the direction of its motion by a part of its length (a few inches in the case of the earth), and a moving clock to slow down in the same ratio, precisely so as to account for the result of the Michelson-Morley experiment. It was as though the swimmer alluded to were required to go up-stream a shorter distance and the clock was running a little slowly, so that he was considered to take exactly the same time in both cases. This hypothesis accounted for all the experimental results which offered difficulty.

The hypothesis of contraction presents two curious features. The first one is that it is incompatible with the ordinary concept of the rigid body as of fixed dimensions under all conditions. Henceforth only rigid bodies at rest are held to be of fixed dimensions.

The second feature is even more significant and deserves partic-

ular attention. It appears that if experiments are carried out on the body in uniform motion as if it is at rest, so that its length is held to be the same as when at rest, then the laws observed to hold are identically the same as if the body is truly at rest in absolute space. On account of the slowing down of clocks and the contraction of lengths as stated, it is at least clear that the velocity of light will appear to be the same for the reference system in motion as for the reference system at rest. The same result holds throughout.

This situation indicates nothing else than that it is experimentally impossible to distinguish between absolute rest and uniform motion in a straight line. Relativity, after being denied a position in the theory by general consent, is entering upon the stage without that consent. The relativity is, however, of a new type because of the fact that the time as well as the space of the reference body in motion is distinct from that of the body at rest. In his theory Lorentz used the term *local time* to describe the time relative to the moving body.

If, despite the fact just referred to, according to which the various reference systems are physically indistinguishable, one deliberately prefers to single out a special reference system and call it "absolute," there can be no objection, any more than there can be to any arbitrary harmless act of the will. However, it is a privilege without physical significance.

Einstein was the first to perceive the true nature of the situation which was giving difficulty, and formulated the appropriate principle of relativity in 1905. The great stroke of critical insight on his part was to be able and willing to abandon the notion of absolute simultaneity which had never been questioned before. It has been stated that the notion of absolute simultaneity implies a significant correlation of events. If the velocity of light were infinite, the correlation would be immediate. It is finite, however, and the experimental facts indicate that the space and time of any undisturbed non-rotating body, *dealt with as though it is at rest,* have exactly the same physical properties as the space and time of other such body similarly dealt with. Why not take as equally valid all these spaces and times, and then attempt to correlate them without employing the hypothesis of absolute simultaneity? The new kind of relativity obtained, in which all such spaces and times appear on an equal footing, and not only mechanical properties of matter but also electromagnetic properties are taken into account, may be termed *optical relativity.* This relativity is spatio-temporal in character.

It is possible now to review the general course of the development of the concept of space and time.

At the outset events were taken to happen as seen, and the notion of absolute simultaneity was accepted as self-evident truth, which was natural under the circumstances.

The first treatment of space turned on the Euclidean analysis of the rigid body and of the attached space which it defines. Any body was equally suitable as reference body, so that (for example) it was legitimate to use either the space of the earth or the space of the sun as the reference space. This was the geometrical relativity of Euclid.

A more careful analysis of bodies, which took account of their mechanical properties, although using the concept of the space attached to a reference body at any instant, made it possible for Newton to go a step further and eliminate rotational relativity. Thus, the sun in the frame of the fixed stars was the superior body of reference in the solar system because it was nearly in the state of undisturbed motion without rotation, which considerations of convenience required of the reference body. Any other star than the sun would serve as well as the sun in yielding a space of reference of the best Newtonian type. Herein lay the mechanical relativity of Newton.

Then came the last step in advance, made possible only by the realization that, just because light travels at a finite velocity, absolute simultaneity is meaningless unless defined by a physical process. If the Newtonian relativity is slightly modified so as to admit the relativity of time, as well as of space, to any reference body in an undisturbed non-rotating state, a more homogeneous treatment of the physical universe is obtained, from the very nature of which it becomes impossible to choose any particular such space and time as possessing a superior validity. Such is the optical relativity of Einstein.

Thus, after space and absolute time have been used in the account of nature for nearly two thousand years, it has been found necessary to replace these concepts by a union of the two, called space-time. Under ordinary circumstances the old and new theories differ inappreciably in their measurable consequences, and yet only the new theory will be found to explain certain phenomena in a satisfactory manner.

The one outstanding fact which must be granted before the new theory of relativity can be properly understood is that the notion of absolute simultaneity is not a self-evident truth, but implies a significant physical correlation of events.

MODERN CONCEPTIONS OF EARTH HISTORY

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GEOLOGY is the history of the earth. I have it on student authority that most history is dry, and ancient history especially is dry. The more ancient, the more dry! And neither Tut-ankh-amen nor Tiglath-Pilesar has anything on Mother Earth, when it comes to ancient history. However, it has lately been discovered that the more history is "boiled down," the juicier it becomes. Wells and Van Loon, working in separate laboratories, have each discovered the process by which continued boiling will eliminate the cellulose and mineral matter of history, and leave a rich, digestible juice. I propose here to use their method, though on a different broth and, submitting the results to a different group of judges, to learn, probably, that I am no Wells or Van Loon.

The history of the earth is read from the rocks of the crust (the lithosphere) and the salts of the ocean (the hydrosphere). The hieroglyphics which we interpret are:

(1) The original character of the rock, whether igneous or sedimentary;
(2) The original structure in the rocks, produced at the time they were cooled, or were deposited as sediment;
(3) The secondary structures, the result of subsequent molar and molecular changes; and
(4) The fossils embedded in the sedimentary rocks, our sole reliance for correlation and dating.

To decipher the meaning of the rock record, almost every phase of modern science must be brought to the task. So varied are the special trainings necessary that it may be said that there are no geologists to-day. There are mineralogists and petrologists; stratigraphers and sedimentationists; paleontologists, paleobotanists and paleogeographers; vulcanologists and seismologists; economic geologists and structural geologists; geochemists; geophysicists and geodesists; glacialists and physiographers; and, finally, embryo geologists and pseudo-geologists, all contributing their mite to the erection of the structure which we call the history of the earth.

A PHILOSOPHY OF GEOLOGY

When men first began to recognize that the rocks of the earth held a record of past changes, their ideas were strongly colored with preconceived notions, derived from various philosophies and re-

ligions. Catastrophes, like the great inundation in which Admiral Noah figured so largely, and like the big fire in the tough old towns of Sodom and Gomorrah, with the associated record-breaking petrifaction of Lot's wife, were the ruling ideas. River valleys were thought to be the erosive result of great waves which swept inland from terribly enraged oceans, or the consequences of tremendous shattering earthquakes of the distant past; the glacial deposits of northern North America and Europe were similarly the record of debacles of horrifying proportions, when whole oceans apparently arose in their wrath and charged across inoffending lands, leaving death, drift and destruction in their wake! The element of vast duration was not in their philosophy. The whole story covered but a few thousands of years.

Later there arose a school of English observers of nature, whose fundamental tenet was dubbed "Uniformitarianism." They argued that the cumulative result of river erosion had formed the valleys which the streams now occupy, that volcanic cones had been slowly built up of the ejectamenta of many eruptions instead of having been heaved up abruptly, that the whole history of the earth, as recorded in the rocks, was to be interpreted in terms of geological changes going on under our very eyes and extended through eons of time. "The present is the key to the past," they said.

Though uniformitarianism was much nearer the truth than the earlier cataclysmy, it is not considered to-day to be the whole truth. I want to raise the question "Is there a philosophy of geology?" "Is there a general scheme?" "A unity?" The answers I shall suggest will be founded on the geological doctrines prevailing to-day, especially in the American school. In the interest of brevity and that desired juiciness, I may be permitted to neglect certain objections and exceptions. At the worst, I shall tell only a few little white lies. Geologists never tell "whoppers"—about geology.

Sources of Energy

Changes great and revolutionary have occurred in the history of the earth. What are the sources of energy which could have produced these changes? Without pursuing the analysis very far—only geophysicists know everything about this subject, and I am no geophysicist—let us note that all sources of energy fall into two groups: (1) Telluric sources—resident within the body of the earth, and (2) extra-terrestrial sources—chiefly our sun. Both groups have worked through all recorded history on the surface of the earth where we read the record.

Geological Processes

Geological changes are, and have been, of three different categories: gradation, diastrophism and vulcanism. Gradation is the sum of all changes which tend to wear down the higher parts of the lithosphere and to build up, or fill up, the lower parts. Diastrophism embraces all movements in the solid lithosphere. Vulcanism is the movement of molten material in and on the surface of the lithosphere.

Gradation embraces the degradational processes of weathering, erosion and transportation to lower places, and the aggradational changes which are a necessary consequence. A circulating atmosphere and hydrosphere are essential. Witness the topography of the moon, where there is neither atmosphere nor hydrosphere—it is apparently unaffected by gradational changes. The source of energy for gradational changes is solar.

Continued without interruption of the process, wind and running water would eventually inevitably reduce the lands of our sphere to low, featureless plains, which the physiographer terms "peneplains." Uninterrupted marginal attack on these lands by the waves of the sea would eventually inevitably reduce the continental areas to shoal water, the depth determined by the lower limit of the ability of waves to erode (wave-base).

These are not purely theoretical conclusions. There do exist to-day large land areas of low relief, essentially planes, beneath which are rocks of very different characters, structures and degrees of resistance to erosion. In only one way could such planes be formed in such situations. They have been scrubbed down by erosion, and are the ultimate stage in a topographic cycle, or cycle of erosion. They are peneplains.

However, not all peneplains now lie in the situation where they were formed. Many are elevated high above the present base-level of erosion in their region, and are being destroyed in a newly inaugurated cycle of erosion. Many mountain ranges carry on their summits the remnants of ancient peneplains. The Appalachians constitute our classic American example. The ancient peneplain is identifiable by an accordance of summit levels over a mass of disordered stratified and igneous rocks, now deeply eroded into a second cycle of mountains.

In contrast with such situations, many peneplains lie buried in the accumulated sediments of the ages. They were submerged, instead of being elevated, after their formation. If we can date the sediment resting on the old land surface, we can place a minimum estimate on the age of the peneplain; that is, on the time since it was completed.

Suffice it to say here that the geological record contains incontrovertible evidence that peneplanation has occurred repeatedly; that the time necessary for its consummation is but a small fraction of the total duration recorded. It is obvious, therefore, that gradation is fully competent to destroy all lands, and that the experiment has been set up for a sufficient time to permit the action to occur. Yet here are the lands of the globe, covering one fourth of the total area, averaging half a mile in altitude, and attaining summits five and a half miles above the sea. If I may be allowed a figure—the lands, like the giant Antaeus, though repeatedly downed by the Hercules "Gradation," have arisen greater than ever! Why are there lands to-day?

Geological Periods

Let us leave this question unanswered for a while and consider another matter. When men, after recognition of the chronologic value of fossils, began to decipher geological history, they used the term "systems" to denominate those strata which contained similar fossil faunas. In general, "systems" turned out to be fairly definite units the world over, and the term "period" came into use to denote the time during which a system was deposited. Each system was made up largely of a series of marine deposits on the continental surfaces. Some of these are so widespread that we know that nearly 75 per cent. of what is now North America was at times submerged. The "system," which is the record of a "period," is the record of a marine transgression on the continent.

Another fact of great significance is that, in general, each system lies on the eroded surface of the subjacent, older one. It is unconformable, in geological jargon, on the older system. From what we have already said, it is clear that these breaks, these unconformities, are records of times when the continent was a land surface. The alternation of systems of marine strata with unconformities is clearly a record of alternating submergences and emergences.

Another noteworthy point is that the strata of the older system in many cases were folded and faulted before the erosion occurred. The record, therefore, in the case of two systems thus related is:

(1) Submergence of a continental surface and deposition of the first system of marine strata;
(2) Emergence of the continental surface;
(3) Deformation, perhaps contemporaneous with (2);
(4) Erosion, perhaps to peneplanation;
(5) Submergence, and consequently deposition of the second system unconformably on the deformed and eroded first system.

Once the shallow seas are spread over a large portion of a continent why should not this condition remain in perpetuity? The answer is—diastrophism! Differential movement in the litho-

sphere! And in this movement, the continent behaved essentially as a unit. Either it was uplifted so that the shallow seas were drained off, or it held its own while the ocean basins were deepened, the result being the same in either case. The lands are renewed because of diastrophism, the shallow epicontinental seas are withdrawn and the sedimentary record interrupted because of diastrophism. Erosion is initiated because of diastrophism.

There remains the question of submergence of the eroded lands. Why has the sea spread so widely after a time of uplift and erosion? The prevailing interpretation for this characteristic feature of the rhythm of earth history is that erosion of the newly uplifted continents produces a quantity of waste which goes overboard into the bounding ocean basins. This displaces water sufficient to cause the submergence. If the present continents were to be eroded to sea level, and the débris to be dumped into the margining oceans, the ocean surface would be raised 650 feet. Such a rise to-day would flood the Gulf of Mexico northward over into the Great Lakes region and there join with another flood up the St. Lawrence embayment, all this without any lowering due to the erosion which we specify should occur to cause it.

During the slow progress of an erosion cycle and the consequent rise of sea level, the encroachment of the sea would be very gradual, and would progress from the periphery toward the interior of the continent. Formations deposited early in any period should be limited in area and near the margins of the continent. Deposits of the middle and later part of a period should have a maximum extent and should be spread from the continental margins to the interior. Now, this is what we find, repeated over and over, in the geological record. The marine invasion extends gradually to its maximum, and, of all areas submerged, the continental interiors are the last to become inundated.

The physical history of a typical geological period, summarized, would be as follows:

A (1) A long time (perhaps several million years) of sedimentation on the continents.
(2) The shallow seas spread more and more widely, reducing the land area to half or less of the total continent.
(3) The surviving lands become greatly lowered by erosion.

B (4) Diastrophism awakens in time to prevent the complete destruction of the lands. The seas are withdrawn into the deep ocean basins, the lands emerge.
(5) Deformation of the new sediments and perhaps mountain-building occurs.
(6) Most of the continent becomes land.

And the period is closed!

The succession of events in a geological period, and the rhythmic succession of the periods themselves, is due to the interaction of the two great sources of energy already named. The part played by gradation is due to extra-terrestrial energy, that played by diastrophism to telluric energy. Diastrophic changes set the stage for the gradational part of the play. Were diastrophism to cease, a complete water-cover for the globe would result and there would be no further history.

Diastrophism Periodic

The rhythm of earth history depends, therefore, on telluric sources of energy and the recurrence of diastrophism. A fundamental question must now be considered—"Why should these great throes of the earth be periodic?" Even more fundamental—"Why should they occur at all?" Studies of the structure of mountain ranges the world over have shown that their making has consisted essentially in a tucking up of the girth of our mother earth. That estimable matron is getting smaller and more wrinkled as she gets older. In the folding and thrusting which piled up the Alps, 75 miles, perhaps much more, of circumference of earth was eliminated at right angles to the trend of this range. In the making of the Appalachians, a shortening of 46 miles was accomplished. In a single great thrust in the Canadian Rockies, an overriding of 15 miles or more is measured.

Lateral (horizontal) compression clearly is the direct cause of such shortenings. In the absence of any evidence to show that this was accompanied by an equivalent spreading elsewhere, and the apparent mechanical impossibility of such a change, the interpretation is made that this is true circumferential shortening, due to radial shortening or shrinking.

We do not yet have an answer to the question, "Why has the body of the earth shrunken during the geological past?" Or rather, I ought to say, we have dozens of answers! It amounts to the same thing either way. But we do know the procedure and the results it has produced: (1) Distributed radially, this shrinkage has drawn down the ocean basins more than the continental platforms and thus has produced those great relief features of the lithosphere; (2) resolved into horizontal components, it has caused great thrusting, apparently from ocean basin tracts against continental platform tracts, and consequent marginal mountain folding; and (3) its distribution in time has been periodic.

What is the nature and condition of matter in the interior of the earth? About this subject we know very little. Its density is high, for surface rock averages 2.6 specific gravity, and the earth as a whole is 5.6. Its rigidity is high, for it has a body tide of elastic

character, and it transmits earthquake shocks with a velocity higher than they would have in tool steel. Though the density is high, anomalies of gravity show that it is not equally distributed. The value of gravity over the ocean basins is 3 per cent. greater than over the continental platforms.

HYPOTHESIS OF EARTH MECHANICS

Based on facts already presented, there has been formulated a hypothesis for the general mechanics of earth shrinkage during geological history. This hypothesis, with many other ideas I am suggesting to-night, we owe to the Nestor of American geology, Professor Emeritus T. C. Chamberlin, of the University of Chicago. Let us review the fundamental facts on which the hypothesis is founded. They are as follows:

(1) Earth's interior is rigid, not molten, as the old ideas had it.
(2) Material beneath ocean basins is heavier than beneath continental platforms.
(3) Diastrophism, on a great scale, has been periodic in the history of the earth.
(4) Continental platforms and ocean basins have been unit tracts during history of the earth.
(5) Major adjustments have occurred between continental platforms and ocean basins.

The hypothesis is as follows:

(1) Increasing density of a heterogeneously aggregated but segmented earth body, due perhaps in part to loss of heat, but much more largely to physical and chemical reaggregation under the enormous pressures in the earth's interior;
(2) Resistance in the exterior portions of the earth's body to yielding *pari passu* with the increasing density of the deep interior;
(3) Consequent accumulation of gravitative stresses, the time of such accumulation measured in millions of years;
(4) Eventual passage of stress into strain—yielding—the heavier ocean basin segments settling more than the lighter continental platform segments —crowding of segments and making of marginal mountain ranges by the horizontal thrusts;—a diastrophic revolution!
(5) The stresses eased, quiescence occurs and gradation now begins a new cycle of erosion, in turn to cause a new flooding over on the continents.

FAUNAS OF THE GEOLOGICAL SYSTEMS

Let us now go back to a subject earlier introduced, but not elucidated—the contrasted faunas of the different systems of rocks. The changes in faunas are so great from system to system that in some cases the doctrine was once entertained that there had been complete annihilation and a new creation of forms of life after the break. Though we now know that some invertebrate forms lived

through several geological periods, in general there are striking faunal changes from period to period.

Consider the situation of the widespread shallow-water marine faunas at the time diastrophism awakens. These shallow seas are drained, and the forms must migrate or perish. The migration itself means extinction for many kinds which have specialized to that fatal extent that plasticity has been lost. The depth, the temperature, the clearness or turbidity, the kind of bottom, the kind of food, all must change, and if the ability of adaptation has been lost, all is lost! Witness the transition from the Paleozoic to the Mesozoic era. Of 10,000 species, but 300 survived. Ninety-seven per cent. became extinct. Only the stress of the physical changes can account for such a faunal change among the marine invertebrates. Thus the diastrophism, springing from interior changes in the earth, and determining the areas of land and water, the topography of the lands and the areas of sedimentation and erosion, determines also great and rapid changes in the forms of life.

The paleontologist, therefore, conceives of two speeds in the evolutionary development of life. One of these is witnessed while physical conditions remain much the same. The other occurs when diastrophic disturbances alter the even tenor of the faunal ways, and is considerably more rapid. At such times appear the characters of major importance—such as distinguish classes—with comparative rapidity.

Climate

A very interesting feature of earth history is the record of revolutionary changes in climate. Of the most recent of these changes, you are all aware. You know that the Great Lakes region, and the northern part of the Ohio, Mississippi and Missouri drainage areas is smeared with a deposit of clay, sand and gravel; unstratified, heterogeneously intermingled. You know that this deposit rests on strikingly planed, grooved and striated surfaces of the bedrock, and that many of the contained boulders are themselves planed and striated. You know that these phenomena are accepted as proof that the region was covered by a continental ice sheet, similar to those of Greenland and Antarctica to-day. Yet this region enjoys a much milder climate now than it did a few tens of thousands of years ago, and with the aid of a certain newspaper scientist, day by day in every way it is getting milder and milder.

If we go below the glacial drift at Chicago, we find the Niagara limestone containing many splendid fossil coral reefs. Aside from the record of an early marine submergence of the region, this constitutes a record of a sub-tropical climate. Reef-building corals to-day can not live in water which cools below 68° F.

The fauna of the Niagara limestone is known about Hudson Bay where there are very similar reefs, and even in Greenland, less than 9° from the North Pole. Not alone was the climate sub-tropical, if we may trust the evidence of the reef-building corals, but it also was non-zonal.

Thus the geological record at Chicago, taken as an example, tells of great climatic changes. But before taking up this subject of the geological oscillations of climate, let us note that probably the most remarkable thing about the history of climate is its uniformity. Throughout uncounted millions of years, the climate of the earth as a whole has remained above 0° C. and below about 45° C., the approximate limits under which living forms may survive. The cause of such uniformity lies primarily in the sun, and the problem is essentially astronomic. Here, however, the geologist humbly tells the astronomer some things about the life of the sun, things the astronomer ought to know. Time was when the astronomer condescendingly told the geologist how much time he could have for the development of life, and the physicist backed him up. Now the physicist is on our side.

The variability of climate, about which I wish to speak for a few minutes, is within these limits of 0° and 45°. There are climatic variations of many orders of magnitude and of time values. Alternations, cycles, pulsations, precessions, fluctuations and oscillations are recognized. I shall discuss only the great oscillations which are intimately related to the geologic periods. The earlier idea of climatic change was a simple one in perfect harmony with the Laplacian or nebular hypothesis, which postulated a molten condition of the early earth. The climate of that earth was *hot*. It was hotter than a July day in Chicago—*i.e.*, hotter than Gehenna! Gradually, with radiation of heat into space, the temperature lowered and finally the first crust of the earth appeared. In other words—hell froze over! The solidified crust has grown ever thicker and thicker, and the climate ever cooler and cooler up to the present. Final crystallization of the remaining molten material, including that liquid mineral water, is just around the corner.

This cheerful view has long since been in the discard. The record of the rocks shows that it can not be true. On the surface of the oldest granites, the primitive crust of the older interpretation, and virtually at the bottom of the whole series of sedimentary deposits in North America, has been found record of glaciation. This occurred when, according to the older view, the granitic crust was still sizzling hot, and the atmosphere contained the present oceans.

It is essentially correct to say that the stratigraphic history of the earth begins with glaciation, and ends with glaciation. But this

isn't all! In the billion years, more or less, of this history, there have been several glaciations (though during most of this billion years, the earth has enjoyed mild, equable, non-zonal climates). One of these glaciations was even more remarkable in its extent than either the earliest or the latest. It saw glacial ice at sea level in peninsular India, lat. 19° N., moving northward, away from the equator.

And, contemporaneous with glaciation, has occurred aridity, the record similarly indubitable. Glaciation and aridity may not seem, at first glance, to be well-mated partners. But consider the earth to-day! It has great areas covered with glacial ice (Antarctica alone has four million square miles of glacial ice, an area equal to half of North America) and it has still greater arid areas. The favoring conditions for both are extensive land areas. Aridity and glaciation are extreme cases of the continental type of climate, as contrasted with the oceanic type.

If the earth to-day, with widespread elevated lands and restricted oceanic spread, is arid in places and glaciated in others, we expect that similarly in the past, widely emergent continents should have been accompanied by glacial and arid climates. The converse of this: the times of widespread seas and low and limited lands, should have witnessed equable climates.

When we examine the geological record, we find this to be the case. Glaciation and aridity have occurred during and immediately after the great diastrophic revolutions. The equable climates have prevailed during the times of diastrophic quiet. The climatic variations swing in unison with the gradational and diastrophic changes already outlined.

That there is a causal relation is clear. It can not be coincidence. But are the varying extents of land and water adequate as direct causes? Is interruption in oceanic circulation from large land areas and constricted oceans, and interruptions in atmospheric circulations from lofty mountain ranges and plateaus sufficient to produce these differences? Almost no one thinks so.

Tyndall long since suggested that variation in quantity of carbon dioxide in the atmosphere might affect climate. This germ of an idea has been developed by Professor Chamberlin into a closely reasoned, strongly buttressed hypothesis. This I shall outline very briefly.

I. Minerals of the deep-seated rocks are prevailingly silicates. These silicates are unstable when exposed to the atmosphere and hydrosphere. Water, carbon dioxide and oxygen enter into combination with metals of the silicates; these compounds thus are de-

stroyed, and oxides, carbonates and various hydrated minerals are formed.

Some decrease in the quantity of these constituents of the atmosphere and hydrosphere must therefore result. Limestone and coal record abstraction of carbon dioxide from the air in enormous amounts in the past.

II. Carbon dioxide, 3/10,000 by weight of the atmosphere to-day, is remarkable in its ability to prevent the escape of "dark heat" from the earth, while permitting the sun's radiant energy to reach the earth. Calculations indicate that to double or to halve this insignificant quantity would raise or lower the average temperature of the earth's exterior by 2° C. This may not seem a very great change, but compare it with the estimates that a lowering of our present average temperatures by 5°–8° C. would reestablish ice sheets over half of North America.

III. The oceans to-day are filled with nearly ice-cold water, even in equatorial latitudes. Only the surface film in the lower latitudes is warm. Cold water settles near the poles, and very, very slowly spreads out over the ocean floors. This is because cold saline water is slightly heavier than warm saline water. The difference in density is very slight, indeed. Were there more widespread oceans, freer entrance of warm waters into higher latitudes and a better thermal blanketing of the whole earth, the contrast would be still less.

Professor Chamberlin suggests that perhaps under such conditions (the conditions of the middle of a typical geological period) density contrasts due to differences of salinity, instead of differences of temperature, might control the great slow overturn of the ocean waters. In such case, greater evaporation (to produce greater salinity) in low latitudes would locate the region of descending waters where they would be warm waters. The deeper parts of the oceans then would become filled with warm, instead of cold, water. The effect of such a situation on world-wide climates is obvious. This would occur in the middle of a geological period when the water-heating plant of the earth would function in its highest efficiency.

IV. Let us now consider the situation toward the close of a typical geological period. A long quiescence of diastrophism has preceded and the spreading epicontinental seas have greatly reduced the land areas. Such as remain are low, featureless and covered deeply with a mantle of the products of decomposition of the underlying rocks. The climate is mild and equable in all latitudes.

But stresses engendered by the shrinking interior have been accumulating during this long quiescence and finally they exceed the

resistance of the great earth body to deformation. A revolution is imminent and unavoidable. As diastrophism awakens, the seas are rapidly withdrawn into the deepened ocean basins, the new lands are uplifted and locally squeezed into massive and lofty mountain systems. Gradients are steepened, erosive forces are more active, the protecting mantle of soil is swept away and unweathered rock is widely exposed. Much of this rock is silicate material and is immediately attacked by the active constituents of the atmosphere.

The draft on atmospheric carbon dioxide would be very great under these conditions, and depletion would lower the average temperatures of all latitudes. Colder air will hold less water vapor and water vapor is even more effective than carbon dioxide as a thermal blanketing agent. Thus the result of decreasing the carbon dioxide would be greatly multiplied. Lowering temperatures of the oceans would give them greater capacity for absorption of atmospheric carbon dioxide and the situation would become still more aggravated.

At this time should come a reversal of oceanic circulation, the cold polar waters now settling and filling the oceans. At such time we should have:

(1) Interrupted atmospheric circulation, because of mountain ranges, and because of permanent high pressure areas over the extensive lands;
(2) Interrupted hydrospheric circulation, because of emergent continents and land bridges;
(3) A less efficient blanketing action of the atmosphere, because of decreased carbon dioxide and water;
(4) A less efficient water-heating action of the oceans, because they are filled with cold water.

Now, the evaluation of such a situation would be extremely difficult. Would the continental climates over the large land areas, untempered by warm oceans, be adequate for glaciation or aridity, the local conditions to determine which? The best way to answer the question is to go to earth history. Here we find that glaciation and aridity have occurred when, and almost only when, this combination of conditions has been realized. And certainly our present-day glaciation and aridity conform to these conditions. We are living in one of these times of extensive and elevated lands, restricted seas and cold-water oceans, and immediately following or in the waning stages of a time of diastrophic adjustment in the body of the earth.

We therefore argue that not alone the alternation of erosion and sedimentation on the continents, the periodic diastrophism and the notable faunal changes, but also the great climatic oscillations of earth history are due to telluric energy, and record an earth body not in complete internal adjustment.

To correct this glacial and arid condition, we must wait on two things:

One, the progress of the new cycle of erosion which eventually
(1) lowers the lands to such gradients that deep soils accumulate and check further carbonation of the silicate rock, and
(2) brims the oceans over on the continents, and decreases the area of land exposed;

Two, the cumulative effect of vulcanism which discharges carbon dioxide into the air, and eventually makes good the loss sustained.

VULCANISM

Vulcanism is one of the great problems of geology. Its status is less advanced and less satisfactory than that of any other I have mentioned thus far. More diverse ideas have been proposed to explain it, more are entertained to-day, than in any other phase of geology. The chief reason for this is that we have fewer data on vulcanism than on any other geological process or group of related phenomena. All explanations of vulcanism, of any merit, must recognize that the rigidity of the earth as a whole proves the absence of a universal molten condition of the interior. Yet liquid rock, flowing almost as freely as water, comes from places in this earth. We are forced to the conclusion of limited magma basins. That these are of long duration, geologically, seems doubtful. Magma basins seem to be determined by favorable conditions of composition, pressure and temperature. As these conditions may change, so the location of magma basins changes. The depth from which lava comes is also unknown, though most opinion places its generation in quantity at no great depth. Some would have it the product of the superficial wrinkling which we call mountain-folding, and thus generated very close to the surface of the earth.

What is the origin of the earth's internal temperatures? The modern view has it that it is secondary to the origin of the earth. It may be due: (1) To physical condensation of the earth, or (2) to chemical reactions forced by the physical condensation, or (3) to radioactivity, or (4) to some combinations of these causes. At any rate, the actual temperatures of the interior depend on the ratio between the rate of evolution of heat and the rate of conduction and radiation of this heat into outer space. Geothermal gradients we possess for only 1–4000 of the total radius of the earth. The temperature curve for 3999–4000 is unknown. And the measured gradients vary greatly, due to local conditions: (1) chemical changes going on in the rocks; (2) original temperatures of lava rock, still retained; (3) circulation of deep-seated water, versus meteoric water.

The force which raises lava to the surface is hydrostatic. The

proverbial violence of volcanic behavior is wholly a matter of gases expanding near the surface. The lava stands quietly in, or flows quietly from, such craters as Mauna Loa and Kilauea. And only in small measure do the Hawaiian volcanoes have associated gas phenomena.

What determines the place of eruption of lava? In general, fracture and folding of the lithosphere are held responsible. Magma is probably passive, perhaps only potential, at great depths. Diastrophism may generate heat locally to cause liquefaction, or may decrease pressure by arching, or both. As a consequence. lavas are frequently extruded in regions or folded mountains during their growth. The deeper the folding, the greater likelihood of igneous extrusion. Yet great extrusions have occurred without the known accompaniment of great diastrophism. The mechanics of such vulcanism is obscure. To enter this field is to venture into pure speculation, and demands the utmost hardihood.

Far more significant than the explosive behavior of volcanic gases is the question of their further history. They are contributions to the atmosphere and hydrosphere. It is largely held to-day that our present oceans and atmosphere are volcanic in origin. The carbonation, oxidation and hydration of rocks during gradational history has abstracted enormous quantities of carbon dioxide and oxygen from the air. The limestones contain many thousand times the amount of carbon dioxide now in the atmosphere, and all of it has been taken from the air. Yet there is no evidence that the air has ever contained much more than it now does.

That atmospheric carbon dioxide is essential to life is obvious. There is as much now contained in the bodies of plants and animals as there is in the atmosphere. That there is constant withdrawal of carbon dioxide from the air has been indicated. Vulcanism has renewed the supply. It follows, therefore, that the emission of volcanic gases, operative through geological time, has been a fundamental condition for the continuance of living matter.

Has vulcanism been rhythmic in earth history? In a general way, yes. It has been spasmodic and much of it is traceable to diastrophism, to which it appears to be subordinate and consequent. No progressive tendency is detectable: (1) In chemical composition of extruded lavas, (2) in modes of eruption, or (3) in degree of activity, since the beginning of the Proterozoic era. Vulcanism, therefore, seems to be a consequence of the lack of physical and chemical equilibrium of the earth body. When that equilibrium is eventually attained, in the far distant geological future, both diastrophism and vulcanism will cease and gradation will attain its final and complete triumph.

The Age of the Earth

We have now reviewed very briefly the part played by the great geological processes during the recorded existence of the earth. One final question arises: "How long has this interplay been going on?" "How old is the earth?"

Estimates vary! Archbishop Usher set the beginning at 4004 years before the birth of Christ, but this figure does not seem to have an adequate basis of observed and properly interpreted fact. Practically every estimate since his time has been greater than the preceding one until to-day we have estimates for the age of the oldest rocks mounting to the stupendous total of a billion, five hundred million years. And the later estimates are based on better evidence than the earlier.

What kind of evidence lends itself to the making of such estimates? I will note briefly three methods of approach to the problem:

I. The ocean salts,
II. The thickness of the sedimentary rocks, and
III. Radioactivity of igneous rocks.

Meteoric water, flowing over and through the rocks of the land, dissolves material and removes it in solution to contribute it to the ocean. Of all the substances dissolved in ocean water, sodium chloride alone tends to accumulate. All others enter into detrital or organic or chemical sediments. For example, calcium carbonate, though much the most abundant substance carried to the sea by rivers, yet in percentage in ocean water is almost negligible. Marine organisms use it in building their hard parts, and after their death, it goes into the sediments.

If we know the total amount of sodium chloride in the sea, and the total annual contribution by streams, it is obvious that division of the larger figure by the smaller would express in years how long the process has been going on; *i.e.*, the age of the oceans, and therefore the length of recorded geological time.

But you see at once that there are several weaknesses in this method.

(1) The area of lands in the past, on the average, has probably been considerably less than at present.

(2) Stream gradients, and therefore vigor of search for soluble substances, has not always been that of the present.

(3) Sodium chloride may be dissolved from rocks at the strand line, by the waves. The solvent power of sea water is said to be about six times that of fresh water.

(4) Sodium chloride may have been leached from the rocks beneath the oceans. Three fourths of the lithosphere now is submerged.

(5) Some sodium chloride has been precipitated out of ocean water in the past. Witness our rock salt beds, clearly of marine origin.

(6) Cyclic salt, escaping from the oceans in wind-blown spray, is in streams but in unknown quantity.

(7) Salt in streams from human contamination, in unknown quantity. A high content of sodium chloride in a stream analysis almost invariably means Homo sapiens somewhere upstream.

(8) Juvenile waters (volcanic waters) with their unknown saline contributions.

(9) Connate waters (fossil sea waters) return via the streams. What amount is to be deducted for this factor?

Evaluating these factors as best we may, the different computations give in round numbers one hundred million years for the age of the oceans.

But a safer plan seems to be to neglect all the sodium chloride and compute on the basis of the unchloridized sodium now being contributed from areas of igneous rocks, and assume that the chloridization occurs after the sodium enters the sea. Most of the chlorine in the salt has not come from leaching of rocks anyway. The igneous rocks do not yield, nor possess, enough chlorine to make the salt of the sea. We assume that this chlorine has come from volcanic gases. Computing on the basis of the unchloridized sodium, the stores of sodium chloride now in the oceans would demand 180 million years for their accumulation. This method also is open to some of the objections to the sodium chloride computation.

One of the earliest, and apparently one of the simplest, methods of estimating geological time is based on the total observed thickness of all geological systems now exposed, and dividing this by the rate at which they have been deposited.

There is no great difficulty in getting the figures for the maximum thickness of all geological systems now exposed. They are commonly quoted as about 70 miles, not including the sediments in the Archean complex.

But the rate of sedimentation—there's the rub! Sedimentation near the mouths of large and active rivers must be much more rapid than along coasts without them. Sedimentation near shore must be much more rapid than far from shore. Sedimentation in the accumulation of a limestone must be much slower than in deposit of a clastic rock. Nothing better than a rough estimate can be used for our problem. And this must vary with the personal equation of the individual computer. As near to an average as I have been able to get is one foot of sediment (all kinds averaged in terms of their relative abundance in the stratigraphic column) in 880 years. This demands three hundred million years for the accumulation of the sedimentary pile.

But what of the unconformities which are present in the sedi-

mentary series? The torn-out page of the book of earth history? The duration of the periods of erosion, recorded by unconformities, is unknown, save that they were long enough for notable biological changes to occur and for extensive peneplanation to occur.

Furthermore, the sediments which we examine and whose thickness we measure were deposited in the shallow waters on the continental shelves. During times of widespread emergence of the continents, detritus from the lands has gone off the edge of the platforms into the abyssal depths and is now inaccessible. Its thickness is unknown.

Still further, let us note that when sedimentation in these shallow epicontinental seas has filled them until their bottoms are close to the level of wave-base, the agitation of the waves and undertow will allow no further deposits to occur. Instead, any sediment contributed will be carried off to deeper water. But will any record of this condition appear in the sediments? These diastems, when neither erosion nor sedimentation was going on in the epicontinental waters, are impossible of evaluation. Some think that they are of great importance in interpreting the record.

Any estimate of the duration of geological time from a study of the sediments must, therefore, be some multiple of the three hundred million years before noted. Perhaps six hundred million, perhaps nine hundred million!

In 1896 Roentgen discovered the X-rays and set the scientific world agog. A year later Becquerel discovered the phenomena called radio activity and the next year Madame Curie isolated radium. Perhaps never in the history of science were more significant discoveries made in so short a time, and were more theories sentenced to the guillotine. The whole conception of the structure of matter had to be remade, a new physics and a new chemistry arose. It is not my purpose, nor my ability, to go into a discussion of the fundamentals of radioactivity. I shall simply indicate the significance of these new discoveries in the problem of the age of the earth.

Radioactive substances are derived from the body of the earth. The parent sources are the uranium and thorium minerals. Each of these elements slowly and regularly breaks down, and liberates alpha, beta and gamma rays, by which the decadence and disintegration may be noted and measured. In the breaking down of uranium, helium is continuously and lead is eventually produced. The end produce of 1Ur is 8He and 1Pb. There are several intermediate stages of the products. Radium is one of these, but its half-value period is only 1660 years, and where found in the rocks, it is a relatively recent product and can not be used in estimating

the age of the earth. But the half-value period of uranium is 6×10^9 years, or six billion years.

How can we use these phenomena in attacking our problem? If we have an igneous rock which contains uranium and helium and lead, and if all the lead and helium present are the product of disintegration of uranium, and if all the lead and helium produced by this disintegration are still contained in the rock, the age of the rock may be obtained.

Use of the helium consistently gives much smaller figures than use of lead for calculations. This is to be expected since the helium constantly leaks away while the inert lead remains.

Another method of using radioactivity for estimating the age of the earth is possible. It is in the study of pleochroic halos. Pleochroic halos are tiny circular spots of color seen in thin section in certain minerals of igneous rocks, under the compound microscope. Each halo has as its center a minute inclusion of radioactive matter. The halo is caused by the discharge of positive electricity by helium atoms (alpha particles) at the end of their trip. Alpha particles from uranium travel with less velocity than those from radium. There is still another rate for the helium atoms from thorium. And the radii of the different rings in the halos correspond exactly with the relative velocities of helium from the different radioactive substances in the nucleus.

Furthermore, artificial pleochroic halos have been made by duplicating the conditions in the rocks, in all but two factors—time and degree of radioactivity.

Now, if a halo of a certain intensity of color can be made in a certain time by a certain high degree of radioactivity, and if the radioactivity of the nucleus of the natural halo is known (it will be low, of course), we may compute the age of the rock in terms of years. That is, the time since the igneous magma solidified and crystallized. Igneous rocks have been formed at various times in the history of the earth. Since they contain no fossils, their age in terms of period and era must be learned by their relations to the fossiliferous sediments. If we can date them in years, we can say how long ago such and such a period occurred.

Not many computations on this basis have yet been made, but nearly all thus far made possess the right relative values. As to actual figures, you will be interested chiefly in the statement that the two geologically oldest granites studied appear to have crystallized from a molten condition 1,125 million and 1,500 million years ago. And these granites may not be older than the oldest sediments!

THE FUNCTIONS OF THE ENDOCRINE ORGANS[1]

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ENDOCRINOLOGY enjoys the distinction of having a definite birthday. On June 1, 1889, Professor Brown-Séquard, then a man of 72, reported before the Paris Société de Biologie a series of arresting observations on the invigorating effects of testicular extracts upon himself. Subsequent work indicates that suggestion probably played a considerable part in the results as set forth, but such was the eminence of the observer and so significant seemed the theory underlying his work that endocrinology became, almost over night, a subject of world-wide interest. The meager annual dribble of endocrine contributions was soon swollen to a flood which has poured forth with increasing volume ever since. In the current (1922) edition of Biedl's well-known "Innere Sekretion" the bibliography alone comprises 480 closely set pages, and only the presumably more significant articles are listed.

To an unusual degree important fundamental discoveries in this field have come from clinical observations. Addison's description of the disease that bears his name includes a large proportion of the most significant facts we have regarding the adrenal glands. Although Schiff's earlier experimental observations, had they commanded adequate consideration, might have been very enlightening, it was actually the clinicians, Friedrich Müller, Murray, Ord, Gull and Kocher, who opened up the field of thyroid physiology. Our first substantial knowledge regarding the physiology of the hypophysis came from Marie in connection with his observations on acromegaly. Thus we have the unusual spectacle of practicing physicians inducting physiologists into important fields of physiology. The debt of gratitude we owe it is a pleasure to acknowledge. It may not be too ungracious, however, to remark that this reversed gradient has proved by no means an unmixed blessing. The apparent fertility of the endocrine field and its ready accessibility soon attracted a numerous band of husbandmen who had neither the time and patience nor the critical acumen for its successful tillage. Accordingly, a large body of literature has accumulated which, for its vagaries, fantastic exuberance and wholesale marvel

[1] Read before Section N (Medical Sciences) American Association for the Advancement of Science, at Cincinnati, December 29, 1923, in the symposium on the endocrine organs.

mongering is perhaps without a peer in the history of modern science.

In all truth, however, the substantiated reality is wonderful enough. When we see misshapen, stunted imbeciles transformed to normal, happy children, diabetics starving in the midst of plenty restored to health and strength, giants and dwarfs produced at will, sex manifestations engendered or reversed before our eyes by control of endocrine factors, who can regard endocrinology as other than a most significant phase of modern biology?

The ultimate aim of science is the control of nature. That part of nature in which most of us are preeminently interested is the human mechanism. That this is subject to the sway of nervous impulses has long been recognized. In addition to nervous control, however, every organ of the body is affected in its development and its functioning by chemical regulators. Of these, the hydrogen-ion is so important that a deviation in the acid-alkaline balance of the blood no greater than that between tap water and distilled water is fatal. The potency of certain of the chemical substances, the hormones, elaborated by the endocrine organs, is as striking as that of the hydrogen-ion. For example, adrenalin, a substance constantly being made in our own bodies, exercises a clean-cut influence when applied to various tissues in a dilution of one part in a hundred millions. Under favorable conditions intestinal motility has been shown to be significantly depressed by a dilution as high as 1 : 330,000,000. Luden has graphically illustrated the meaning of this statement. Modifying her illustration somewhat, suppose we set out to dilute an ounce of pure adrenalin crystals with water to a point at which the drug can no longer be detected by the intestine assay method. The necessary water will be conveyed in ordinary street sprinkler tanks holding 625 gallons each. The tanks deploy in procession at intervals of about 25 feet, or 200 to the mile. When the contents of each tank in a procession extending 20 miles has been poured into the ounce of adrenalin the reaction will have just disappeared. At the meeting of the American Physiological Society this year Abel reported the isolation of a product from the pituitary which is even more potent. To dilute an ounce of this to the ineffective point the procession would have to be not 20 but 1,000 miles in length. In case of a highly sensitive test tissue the procession would have to be more than 5,000 miles in length. These quantities, it may be emphasized, involve no element of the fanciful; they are realities. Such magnitudes almost bring endocrinology into kinship with astronomy.

An adequate consideration of any one of numerous phases of the physiology of any one of several different incretory organs would more than exhaust the time available for this address. It is possible

to cite but a few interesting observations. The necessity of ignoring many important recent studies is regretted.

THE PINEAL

Proceeding from above downward we may first mention the pineal body, a structure homologous with the parietal eye of certain extinct lizards. It is formed as a dorsal evagination of the midbrain. Descartes taught that the organ is the seat of the soul. The pineal reaches its greatest development, however, by the age of seven and then recedes, a fact hardly consistent with Descartesian theology. The literature on pineal function is equivocal. There are a few clinical cases recorded in which apparently destructive tumors of the gland have been associated with premature development of the body and the sex organs, a condition formidably indicated by the octopedalian vocable, *macrogenitosomia precox*. Attempts to produce a similar condition experimentally have been attended with many difficulties. The most favorable subjects for such work are fowls, because of their well-marked sex stigmata and the relatively easy approach to the pineal. Rather a respectable number of investigators have obtained augmented growth and precocious puberty after pinealectomy in this form. In rats, Horrax, in 1916, obtained rather doubtfully positive results, but after careful extirpation of the pineal in puppies Dandy more recently has obtained convincingly consistent negative results. In both clinical and experimental investigations the possibility of local brain involvement rather than of pineal deficiency as the essential causal factor has to be considered and has not been ruled out.

Feeding experiments have given varying results in the hands of different investigators. The trend of the evidence, so far as it is of positive tenor, indicates that pineal feeding, just as pineal destruction, causes precocious development. In view of the negative results in a considerable number of careful investigations one might be led to suppose that pineal substance is only inert organic débris, that the rather indefinite positive results secured from its administration are to be ascribed to coincidence, were it not for the report of McCord and Allen and more recently of Huxley and Hogben that it causes a sharp contraction of the chromatophores of tadpoles, giving them a peculiar translucent, ghostly appearance.

It is to be noted that in this as in all cases negative results from the administration of gland substances are of practically no final significance because of the uncertainties involved in the preparation of the gland material. An organ might conceivably exercise an important incretory function without at any one time containing more than a trace of its specific hormone. Moreover, even if the hormone were present in fairly high concentration it might all dis-

integrate quickly after death or be destroyed in the process of manufacture of the gland product. The ideal check on these possibilities is to demonstrate the presence of the given hormone in the blood or lumph flowing from the organ. This has not as yet, however, been accomplished with certainty in case of any but the adrenal glands.

The Hypophysis

The hypophysis is a composite organ formed embryologically by an outgrowth from the primitive pharynx meeting and investing an outgrowth from the ventral side of the brain to which it remains attached by the infundibular stalk. In postnatal life it is located in almost the exact center of the head. The pharyngeal component is epithelial in nature and comprises the anterior lobe, the pars intermedia and the investing layer of the posterior lobe and stalk. The posterior lobe is made up mostly of neuroglia which supposedly have only a mechanical, supportive function. Paradoxically, however, it is from the posterior lobe that the potent secretion often referred to as pituitrin is secured. It is probable that the pituitrin is actually formed by the epithelial cells of the pars intermedia and more or less as a matter of accident concentrated in the neural lobe en route to the third ventricle of the brain, where it is added to the cerebro-spinal fluid.

It was formerly believed by many endocrine students that complete extirpation of the hypophysis is necessarily a fatal operation. That this is not the case, however, has been shown rather conclusively. Recently, Brown, of Chicago, has removed the glands by cautery from 66 dogs. Many of these survived and developed characteristic symptoms, but in five cases no symptoms whatever could be detected following the operation, although careful microscopic study of the tissue about the original site of the hypophysis failed to disclose any remnants of it.

In many cases a depression of growth that seems to amount to dwarfism results from pituitary extirpation. This finding is concordant with the fact that in the Levi-Lorian type of dwarfism in man pituitary hypoplasia seems to play a causal rôle.

The condition of *dystrophy adiposogenitalis* often resulting from hypophysis extirpation has been recognized clinically for nearly a century. It was first described, though not in an entirely typical form, by Mohr in 1840; its association with hypophyseal lesions was recognized by this observer. It was through the work of Fröhlich, however, that it became generally recognized as a definite clinical entity. In the Fröhlich syndrome in man the fat tends to have a peculiar distribution, being especially marked in the mammary region and about the pelvic girdle. A high tolerance for carbohydrate, metabolic sluggishness, flabby musculature and some-

times somnolence are characteristically found. Dickens's "Fat Boy," "Joe," was obviously a victim of this malady. Polyuria or *diabetes insipidus* is frequently but not invariably an accompanying symptom. Although sexual infantilism is commonly seen, the sex organs may be fairly well developed, but axillary and pubic hair growth depressed and in the male show the feminine type of distribution.

Many clinical observers believe that the Fröhlich dystrophy is due, not to general hypophyseal defects, but exclusively to involvement of the posterior lobe and the pars intermedia. The evidence for this belief is not convincing, however, and some doubt is cast upon it by reported beneficial effects of administering anterior lobe substance in the Fröhlich dystrophy.

Indeed, recent work has opened the question whether any part of the pituitary is involved in this condition. Leschke, Houssay, Camus and Roussy and more recently Baily and Bremer, working in Cushing's laboratory, have shown conclusively that the adiposogenital dystrophy in its classical form can be produced merely by injury of the tuber cinereum, a part of the base of the brain lying near the attachment of the pituitary stalk. In various cases of the full-blown dystrophy no microscopic evidence of pituitary injury could be detected. The possibility remains, however, that the brain injury may have involved secondary trophic disturbances in the hypophysis.

A great deal of work has been done on the pharmacology of pituitrin. Houssay, of Buenos Aires, has published a monograph of 350 pages on hypophyseal extracts, most of which is concerned with pituitrin. This substance injected parenterally or directly into the blood stream causes a marked stimulation of the heart and the smooth muscle throughout the body. Among other effects, this results in augmented blood pressure and increased gastro-intestinal activity as well as uterine contractions, especially in pregnant animals. For brief periods in anesthetized animals pituitrin causes an augmented flow of urine, usually with vascular dilatation in the kidneys. Paradoxically, however, its effect in the intact, unanesthetized subject is to check diuresis, either that induced by copious administration of fluids or that spontaneously arising in diabetes insipidus. Rogers has noted that in pigeons rendered poikilothermous by injury of the optic thalamus pituitrin causes a marked rise in body temperature. In normal animals, however, the thermogenic effect falls within the limits of diurnal variation. Achard and others have shown that pituitrin injections cause a considerable rise in blood sugar. Burn has recently shown that the dangerous fall in blood sugar resulting from an overdose of insulin can be promptly relieved by pituitrin.

Attempts to demonstrate the existence of a physiologically active substance in anterior lobe material have until recently given negative or at least unconvincing results. Robertson described an extract, *tethelin,* as an active principle which has a marked influence upon growth. The work has, however, failed of satisfactory confirmation. It is now regarded as a variable mixture of lipoids. In a few instances Goetsch noted greater reproductive activity in rats receiving anterior pituitary substance than in their controls, but his controls appear not to have been normally fertile. Numerous other investigators have obtained negative results in such experiments. Uhlenhuth, however, in *Amblystoma tigrinum* succeeded in producing giants by feeding anterior lobe substance from cattle. His experimental animals were 25 per cent. larger than the largest normals which he was able to rear or to find in other collections. The growth of tadpoles delayed by extirpation of the hypophysis has been shown by Smith and by Allen to be markedly stimulated by injections of anterior lobe extract, the experimental subjects outgrowing their normal controls about twofold. Similar results were obtained by Allen and by Swingle from anterior lobe transplants. The latter observer has reported that the tadpoles of two species of frogs which normally remain in the larval stage for long periods can be made to metamorphose promptly by ingrafting anterior lobe of the hypophysis of adult frogs. This effect is apparently correlated with the marked hyperplasia of the thyroid that ensues. Smith also has recently reported a similar thyroid hyperplasia in tadpoles following injections of anterior lobe extract. Particular interest attaches to the work of Evans and Long on the effects of bovine anterior lobe extract in rats. These observers were able to demonstrate conclusively an overgrowth that can fairly be described as gigantism.

Corroborative of experimental findings are the facts that the sella turcica of the sphenoid bone in which the hypophysis is located is enlarged in spontaneous gigantism and decreased in some cases of dwarfism. Acromegaly, a condition arising with hypophyseal enlargement after puberty in man, has not been reproduced experimentally.

The Thyroid

The outstanding features in the physiology of the thyroid gland are so well known as scarcely to need discussion. Thyroid deficiency of extensive degree often appears spontaneously and can readily be produced experimentally. The subject, either human or other mammal, remains a stunted, pot-bellied, bandy-legged imbecile. It exists on a low metabolic plane, as is evident from its sluggishness, reduced body temperature with susceptibility to cold, dry hair and skin, and failure of sexual development. Lesser degrees of thyroid

deficiency, gradually merging into normality, with correspondingly developed symptomatology, can be recognized. That the conditions are due directly to thyroid deficiency can be demonstrated by the complete restoration to normality by thyroid feeding. It should be noted, however, that if treatment is too long delayed deterioration may progress to a point no longer amenable to correction.

Perhaps the most remarkable result of thyroid administration is its stimulation of growth. In so-called cretins several inches increase of stature in a year is not uncommon. Moreover, the leanness of certain hypothyroid subjects can be strikingly ameliorated by thyroid treatment. These characteristic anabolic effects of the thyroid hormone are often forgotten in endocrine philosophizing.

If thyroid substance be administered in amounts much surpassing the normal or if the gland spontaneously becomes greatly overactive symptoms of intoxication arise. The oxidative processes of the body are increased, sometimes 100 per cent. Other characteristic results are tremors, rapid pulse and nervous excitability often leading to stubborn insomnia.

The isolation by Kendall of a potent, chemically constant, iodin-containing substance, *thyroxin*, has rendered possible some interesting quantitative studies. There is considerable evidence that thyroxin represents a true "active principle." From studies on hypothyroid human subjects data have been obtained indicating that the amount of thyroxin in the adult body outside the thyroid gland is approximately one fourth of a grain. About one one hundredth of a grain a day is required for normal health. It is startling to contemplate that about three and a half grains of this substance a year is all that stands between any of us and imbecility. The effect of a single dose of thyroxin develops slowly and persists for from two to three weeks.

The thyroid is subject to seasonal influences; it shows evidence of depression during the warm months and of increased activity in winter. It reacts quickly to changes of diet. In old age gradual deterioration of the thyroid characteristically occurs. Whether, however, this is cause or effect presents an interesting problem. There are in the literature a number of reports of amelioration of the signs of senility following administration of thyroid substance, but the problem needs further study.

These are but a few bits from a large body of evidence. The time is not yet ripe for a definite generalization, but it seems probable that the function of the thyroid gland is to serve as a slowly acting regulator of energy discharge to aid in adapting the animal to its environment.

The Parathyroids

The parathyroid glands in man are four in number, situated in close relation to the thyroid. In the adult they are about the size of peas. Removal of the glands commonly results in a characteristic condition, *tetania parathyropriva.* Objectively, this is marked by tremors, clonus and various degrees of muscular contracture. The galvanic excitability of the motor nerves is augmented to an extent more or less paralleling the degree of glandular deficiency. In some cases tetany fails to appear, but the subject may develop cachexia. Defects in development of the teeth often occur, a fact probably correlated with disturbed calcium metabolism. Salversen has recently confirmed older reports that the amount of calcium in the blood in this condition is considerably decreased. That calcium administration materially alleviates parathyroid tetany is well known.

The classical symptomatology of parathyroid deficiency suggests intoxication. Koch, followed by Paton and his collaborators, found in the urine methyl guanidine, a substance closely related chemically to creatin. Injection of methyl guanidine was found to cause augmented neuromuscular irritability. This is not, however, amenable to calcium treatment as is parathyroid tetany. Hammett has found that excitable wild rats are much more susceptible than gentle subjects to parathyroidectomy. This fact he tentatively correlates with increased creatin formation associated with augmented muscular tonus. Whether or not methyl guanidine be a significant factor, it seems clear that some sort of toxin is involved. Luckhardt, Dragstedt and their associates have shown that measures directed toward preventing toxin absorption from the alimentary tract and facilitating prompt elimination are highly efficacious in controlling parathyroid tetany. The omission of meat from the diet, avoidance of constipation and the copious use of fluids may suffice to keep a dog in excellent health despite complete parathyroidectomy. Such animals can even go through pregnancy without disturbance, although this condition ordinarily causes marked accentuation of symptoms and, indeed, frequently death.

Although parathyroid extracts have been widely used therapeutically, there is no very satisfactory evidence of their potency. Parathyroid grafting has as yet led to few if any convincing results.

The Adrenals

Speculative endocrinology of recent years has largely centered in the adrenal glands. Despite a very large body of careful observations these organs remain a mystifying puzzle. The adrenals are situated at the anterior poles of the kidneys. In size and shape they resemble large beans. Like the thyroid, they are richly vascu-

larized. Each gland consists of two parts, a cortex and a medulla. Destruction of the whole gland or of the cortex in most animals is rapidly fatal. In some animals, however, enough accessory adrenal tissue is present to prevent death. In the absence of the adrenals the subjects develop muscular weakness, low blood pressure and fall of body temperature. In the hands of most investigators attempts to produce partial functional inadequacy of the glands have not been successful; either no detectable effects are secured or the animals promptly die. There is some evidence, however, that trophic disturbances, particularly of the skin, may develop as a result of a properly graduated adrenal deficiency.

Numerous attempts have been made by extirpation experiments to differentiate between the functions of the cortex and the medulla of the gland. Biedl, for example, studied the problem in certain fish in which the two structures constitute separate organs. The results indicated that it is the cortex that is essential to life. Several investigators have lately attempted to determine the matter in higher animals, especially dogs. With a curette or cautery the central, medullary part of the gland has been destroyed. It is, of course, necessary in such studies to check microscopically the amount and distribution of the destruction. In general, the results have been consistent in showing that animals survive the complete loss of the medulla, but that when the cortex is reduced below a critical amount death supervenes. This is a surprising fact, because it is from the medulla and not the cortex that the recognized active substance in adrenal extract is derived.

There are on record a considerable number of cases, mostly human, in which spontaneous hyperplasia of the adrenal cortex has been associated with the condition of virilism. In young males this is manifested by precocious puberty; in older subjects hirsutism is the chief objective sign. In females it is said that the normal sex stigmata may be accentuated, but more often the subject becomes masculinized. The condition is reported to be often associated with marked increase of bodily strength. Extracts of adrenal cortex have not been proved to be effective.

From the medulla of the gland, however, and to a much less extent from outlying chromophil tissue associated with the sympathetic ganglia the substance, adrenalin, is secured. This is a powerful stimulant of the sympathetic nervous system. It causes augmentation of the heart beat and of other functions stimulated by the sympathetics. The gastro-intestinal tract, however, is inhibited by adrenalin as it is by sympathetic stimulation. There is evidence that the ganglion cells are affected to some extent, but most of the influence of adrenalin is exerted upon a hypothetical "re-

ceptive substance" interposed between the sympathetic terminals and the effector cells.

One of the most striking reactions to adrenalin is increase in the amount of sugar in the blood. This is probably due largely to stimulation of the liver cells. The terminal bronchi in the lungs are dilated and the respiratory center directly or indirectly stimulated. Basal metabolism is materially increased by subcutaneous injections of as little as 0.5 mg in an adult human subject. There is a mass shifting of the blood from the splanchnic domain and the skin to the skeletal muscles. The efficiency of the skeletal muscles, at any rate in cats and dogs, can readily be shown to be increased by the injection of adrenalin. The recovery from fatigue or asphyxia is much accelerated. In the cat, as Gruber has shown, it is possible by perfusing it with adrenalin to resuscitate skeletal muscle even two hours after death so that it will respond vigorously to stimulation. The coagulation time of the blood is lessened by adrenalin in physiologic doses.

Cannon has offered a theory that pain, fear, rage and asphyxia, conditions attendant upon emergencies arising in the environment, cause augmented adrenal discharge. This is the so-called *emergency theory*. As Cannon points out, the aforementioned reactions to adrenalin would all be of adaptive value in enabling the animal to go safely through a conflict with an opponent.

The history of the vigorous controversy that has arisen over the emergency theory serves to illustrate the difficulties attending investigation in the field of endocrinology. After more than ten years of exacting study by some of the world's foremost physiologists wide divergence of views still maintains. The problem is essentially that of control of adrenal discharge. That stimulation of the sympathetic fibers going to the adrenals evokes adrenalin discharge is an unquestioned fact. That the glands are under central control is rather convincingly demonstrated. That pain, strong emotions and asphyxia cause a marked overflow of impulses through the sympathetic system is generally recognized. The assumption that the sympathetic fibers going to the adrenals share in the reaction to the conditions mentioned has an inherent probability little short of conclusive. Final irreproachable proof of this assumption, however, has been difficult to secure. Numerous observers have reported bodily changes such as are produced by the injection of adrenalin when the experimental animal has been subjected to strong sensory stimulation or to asphyxia. In most reported cases removal of the adrenal glands has materially lessened or abolished these reactions. In some instances, however, ambiguous or negative results have been secured. The most recent extensive investigation of the problem reported is that of Kodama. In this study the "vena cava pocket"

method of Stewart was employed, the efferent blood from the adrenals being collected and assayed outside the body. Stewart, the most vigorous opponent of the emergency theory, maintains that this is the ideal method of studying the problem. In most of Kodama's animals clean-cut evidence of increased adrenal output, often more than 100 per cent., was obtained after strong stimulation of sensory nerves.

The greatest obstacle to the solution of the problem would seem to lie in the fact that reactions to adrenalin are conditioned by a number of factors often overlooked. In the case of blood pressure, for example, adrenalin may cause an increase or a decrease, depending upon dosage, speed of injection, initial blood pressure, body temperature, hydrogen-ion concentration of the circulating medium, presence or absence of tissue extractives and perhaps conditions in other endocrine organs, especially the thyroid. Under such circumstances uniform results would be by their very consistency suspect. Before any crucial experiment either favoring or opposing the emergency hypothesis unless perhaps the direct assay method can be accepted as final it must be shown that the aforementioned conditioning factors are controlled. That this could be conclusively shown is doubtful. It seems obvious that the problem should be attacked on a statistical basis. One gathers the impression from the pertinent literature as a whole that the data mathematically treated would show a high correlation between presence or absence of the adrenal medulla and the vascular reactions to pain or asphyxia.

Pende has recently attempted to revive the so-called tonus theory of adrenal function. In view of the facts that adrenal deficiency results in striking fall of blood pressure and large doses of adrenalin cause a remarkable rise the plausible assumption was widely held for two decades that the essential function of the adrenal glands is to maintain sympathetic and, especially, vascular tonus. The theory assumes that the adrenal glands are constantly discharging adrenalin in minimal pressor quantities. Superficially attractive as the theory is, it fails to accommodate certain facts. If the glands are constantly pouring out pressor quantities of adrenalin, a notably evanescent substance, sudden occlusion of the adrenal veins should result in a prompt fall of blood pressure except in those occasional instances in which a free collateral outlet through the kidneys is open. But a depressor effect is not seen for hours after adrenal occlusion if the initial blood pressure is anywhere nearly normal. If the adrenal glands are constantly discharging minimal pressor quantities of adrenalin the injection of a slightly greater amount should lead to increased blood pressure. A fall of pressure, as a matter of fact, results. Adrenalin, in addition

to having a pressor influence, is a potent paralysant of gastro-intestinal motility. The threshold of this paralysant effect is lower than the vascular pressor threshold, hence adrenalin could directly maintain blood pressure only at the expense of intestinal ileus. An alternative version of the tonus theory is that constant discharge of minimal quantities of adrenalin is necessary for the maintenance of sympathetic irritability. Direct experimentation in the writer's laboratory, however, showed that the injection of small quantities of adrenalin over a considerable period of time results, not in facilitating sympathetic reactions to stimuli, but often in materially impeding them.

Another theory as to the normal function of adrenalin can be deduced from the fact that in very minute quantities it augments basal metabolism. The disproportion between the quantity involved and the effect produced as well as direct experimentation indicates that adrenalin serves to catalyze some reaction in the process of fuel oxidation. It is probable that the intervention is in the immediate oxidation reactions, that is, that the substance serves as a respiratory catalyst.

Possibly related to the catalytic theory is the statement agreed upon by most investigators—Stewart and Rogoff dissenting—that the adrenals play an important rôle in resistance to fatigue. Mauerhofer has recently reported, for example, that rats surviving double adrenal extirpation and meeting ordinary conditions of life in an apparently normal way are very susceptible to fatigue and usually die after enforced activity. Hartman for the past two or three years has been studying the relation of adrenal discharge to muscular efficiency in cats working in a revolving cage. In his most convincing experiments the pupil on one side is completely denervated and by its dilatation serves as a signal when adrenalin is being discharged. Briefly, Hartman has found that often when the animal at enforced labor begins to show signs of distress the denervated pupil suddenly flares out and the cat simultaneously acquires "second wind." It is suggested that the warming up of athletes is partly a matter of arousing enough stimuli to initiate adrenal discharge. In other experiments the adrenal glands were removed or denervated, either of which procedures prevents any detectable discharge of adrenalin. Such cats were then fatigued to the point of distress and adrenalin artificially administered. In many instances this was shown materially to improve performance.

One other theory of adrenal function, though involving the cortex rather than the medulla, has long persisted, namely, that the gland is an important detoxicating mechanism. There are on record many observations indicating that the adrenal glands undergo degenerative changes after the administration of poisons.

Following the profound toxemia resulting from severe burns, adrenal destruction has often been reported as extensive. Moreover, animals, especially rats, that survive adrenal extirpation and remain in apparently good health show increased sensitiveness to a variety of poisons such as curare, cobra venom, morphine and diphtheria toxin (Lewis), whereas injections of adrenal extracts (whole gland) are reported to protect the animal from simultaneously injected toxins.

In view of the fact that adrenalin in relatively large doses produces marked hyperglycemia a theory that the suprarenals play an important rôle in the pathogenesis of diabetes mellitus has had considerable currency. Recent evidence, however, convincingly opposes this theory. Houssay, and more recently Stewart and Rogoff, have found that dogs deprived of the adrenal medulla and of most of the cortex develop characteristic diabetes after pancreatectomy, just as do normal dogs.

The Pancreas

A fascinating chapter in endocrinology has recently been unfolded as a result of the epoch-making studies on the pancreas. It is a matter for congratulation that we are to hear to-day an account of these studies from one who has had a large part in them.

The Sex Glands

Just now the sex glands are coming in for a great deal of attention, much of which could be gladly spared. There is a real danger that in the natural revulsion from prurient exploitation important experimental accomplishments may fail of due consideration. Through the results of centuries of experience the effects of gonad deficiencies in man and in the domestic animals are well known. It was not until recently, however, that it began to be understood that results of castration are due to resulting endocrine deficiencies.

Although not admitted by all students, the conclusion is almost assured that the hormone of the male gonads is formed in the interstitial cells of Leydig. The reproductive cells can be destroyed by x-rays without any detectable influence on the sexual habitus or psychology, a fact that should be of great interest to practical eugenists who are concerned with the problem of propagation of the unfit. Occasionally an individual is found to have sex glands in which no generative elements are found, but, if the interstitial cells are present, this subject also appears normal. On the other hand, if the gonads containing only interstitial cells and the connective elements are extirpated, the symptoms of castration promptly appear. If the operation is done before puberty, the subject remains sexually infantile throughout life. If done in the postpuberal period, there is a regression of the secondary sex characters to the

infantile condition. Not only, however, are the sex organs affected, but also changes are noted in the functions of the nervous system and in the psychology of the subject. A method recently described by Sand would seem to render easily possible final proof as to the rôle of the interstitial cells. This investigator reports that if the testes are transposed to an intra-abdominal situs the generative elements soon disappear, leaving only supportive and interstitial cells. Under such conditions he states that normal sexual development and reactions are maintained.

Some years ago Steinach reported a series of experiments, demonstrating the incretory functions of the gonads. A young male guinea pig was castrated and allowed to come to maturity. It remained sexually neutral. Similarly, a female from which the ovaries were taken remained in a neutral condition. If, however, into a spayed female the testes of a brother were grafted, the subject then developed various male attributes. The bones showed masculine characteristics in form and size, the hair became coarse and the subject inclined to dalliance with normal females. If the conditions were reversed, ovaries from the female being grafted into a castrated brother, this subject showed female development, the mammary glands hypertrophied and the animal was wooed by normal males. The work has been confirmed by Lipschütz in Dorpat, Sand in Denmark and Moore in this country. Thus the important fact appears to be established that in some experimental animals, at least, very striking transformations toward either the feminine or the masculine type can be induced by gland grafting. Steinach reported that he was unable to produce hermaphrodites, but Moore and Sand have succeeded in the endeavor, the individual having both viable ovary and testicle gland elements, and showing mixed male and female characteristics.

Recently Steinach has been working along somewhat different lines. With care to avoid injury of blood vessels, the efferent ducts of the testes are ligated. Following this, a marked degeneration of the sexual cells takes place. Steinach's theory is that the nutrition of the gland is then all thrown to the interstitial cells, which thereupon form an augmented amount of their characteristic hormone. The subjects are reported both by Steinach and by Sand to show varying degrees of rejuvenation. To what extent the effects are subjective is, of course, difficult to determine. Sand, however, has reported a ligation experiment in a dog showing marked evidence of senility. After the operation the animal became much more active, its nutrition improved and it took up as a favorite diversion accompanying its master on bicycle rides. In this case, suggestion could hardly have played a part; but we should not forget the long arm of coincidence.

At least brief mention should be made of Lilly's studies on free-martins. It has long been known that the female of bisexual twins in cattle is often sterile and develops various masculine characteristics. This is plausibly explained by the fact that the fetuses have an intercommunicating blood stream in which the hormones of the male twin could gain access to the body of the sister. It is supposed that under these conditions some preponderating male hormone, presumably from the gonads, suppresses the influence of femininizing factors.

As regards the female gonads, the source and nature of their hormones has recently been illuminated by the work of Loeb, Allen and Doisy, and Evans and Long. Although previous evidence permitted a somewhat plausible deduction that the follicular fluid contains an active substance, final convincing proof has but recently been offered by Allen and Doisy. Using rodents as experimental animals, these investigators have shown that the injection of follicular fluid results in striking sex stimulation. By relatively simple means a partially purified, highly potent extract has been obtained. From one to three injections of this extract into spayed animals produced typical estrual hyperemia, growth and hypersecretion in the genital tract as well as growth of the mammary glands. The spayed females exhibited typical mating instincts, taking the initiative in courtship and accepting congress with the male. Several injections of active extract were made into animals immediately after weaning, at an age of from three to four weeks. They became sexually active in from two to four days and from twenty to forty days before their normal litter mates. It would seem that this follicular hormone is the source of the stimulation whereby the estrual and presumably the menstrual cycle is maintained.

That the estrus is held in abeyance during pregnancy is well known. That the inhibitory influence emanates from the corpus luteum was a plausible deduction. The careful studies of Loeb have gone far to prove its correctness. Long and Evans have recently reported that in female rats treated with anterior lobe hypophysis extracts estrus is depressed or entirely inhibited. The ovaries of these animals are approximately twice the normal size, the added bulk being made up of persistent corpora lutea. In these cases, along with depressed estrus, uterine hypoplasia is noted.

Almost simultaneously there have appeared three developments in the field of endocrinology that may take preeminent rank. These are the isolation of insulin, of the growth-promoting substance of the hypophysis and of the sex-stimulating substance of the ovary. These discoveries are of first-rate importance not only on account of their immediate obvious significance but as affording means for

the attack of numerous difficult problems of far-reaching importance.

That the difficulties in the way of endocrine research have often been underestimated and that the literature contains a deplorably high proportion of immature contributions—or worse—is a regrettable fact. The widespread skepticism regarding endocrinology, or, at any rate, of much that seeks credit as endocrinology, is no doubt a manifestation of good scientific common sense. Despite the sins committed in its name, however, endocrinology constitutes one of the major developments in modern biology. While the subject demands rigid but open-minded skepticism, it would be deplorable if carping distrust or over-emphasis of its inherent difficulties should discourage investigation.

The field bristles with important problems at every turn. Indeed, some of the most elementary facts remain yet to be determined. What is a normal human thyroid? A normal adrenal? No one exactly knows. There is need of many exacting studies of the architecture and quantitative make-up of the incretory glands such as Hammar has made of the thymus and Rasmussen of the hypophysis. What part do the hormones play in determining the constitutional make-up of individuals, the establishment of family or racial characteristics? Keith, Pende and other writers have speculated engagingly upon this problem, but clean-cut evidence is notably lacking. This problem demands extensive and intensive investigation. What part do endocrine factors play in the onset of old age? That the body cells are potentially immortal seems sufficiently established. Death is but the last stage of stable, cellular equilibrium. Hormones are known to exert a profound influence upon cellular functions. That a detailed knowledge of endocrinology might double the allotted threescore years and ten of human existence is by no means a fantastic dream. What part do the incretory organs play in adaptation? This question epitomizes a hundred important problems that are crying for solution.

The field is wide. In no field of biology is the path of the investigator beset with more pitfalls and dangers. That the difficulties are becoming widely appreciated is an encouraging sign. Endocrinology offers no easy path to fame, but to the man who is willing to pay the price of patient, exacting work the field beckons enticingly.

THE DEVELOPMENT OF ASYMMETRY[1]

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It has been shown that the median plane of symmetry of the embryo, when not impressed on the egg by its stiff enveloping membrane, may in certain cases be traced back to another external agent, such as the path of entrance of the spermatozoon, or possibly, in one case, to pressure acting on the egg in the oviduct. It was not found necessary, therefore, to assume that a bilateral structure is present in the protoplasm of the unfertilized egg, as long as its origin could be explained as arising from extraneous sources. There is another group of cases in which structures that are asymmetrical develop. It is as important to discover the origin of asymmetry as to find out how a bilateral symmetry arises in the egg, and the situation is all the more interesting because the asymmetry is generally imposed on forms that have a fundamental, structural bilaterality.

The Asymmetry of Flat-fish

While most fish keep the dorsal side uppermost, flounders and soles lie on the bottom of the sea on one side. The anterior end of the body in particular is very asymmetrical. Both eyes lie on the side that is uppermost. The change in position in one eye is paralleled by extensive changes in the shape and arrangement of the bones of the head. Other organs than the head are also much affected; in fact, evidences of asymmetry may be found throughout the entire body. Yet the young flounder is, at first, like other fish. It has a bilateral form and swims with its dorsal surface uppermost. When a certain stage is reached, the young fish sinks to the bottom, but even before doing so the changes that lead to its later asymmetry have begun to appear.

Some species lie on the right side (summer flounder), others on the left (the halibut). Rarely a flounder is caught that is "reversed." These may seem to indicate that at the beginning both sides have the same potentiality. Such a view, if true, would still leave unexplained why certain species, with the rarest exceptions, turn on to a definite side—right or left, as the case may be.

The changes that take place when the asymmetry appears have been examined by several embryologists, Pfeffer ('86), Williams ('02), Mayhoff ('14), but the fullest account is that of Kyle ('21) who finds the earliest evidence of asymmetry in the twisting of the

[1] Chapters from Experimental Embryology. III.

gut, and in the position of the swim bladder and other visceral organs. The twist gradually extends forward as the embryo turns to one side, and finally the head becomes involved. Kyle points out that in the earliest stages the asymmetries are not unlike those found in other fishes, but in these a compensation takes place enabling them to retain a dorso-ventral position. In the flat-fishes the changes progress until the effects are far-reaching. Kyle seems inclined to think that these changes in the young fish have forced the flat-fishes to adopt a bottom life, rather than that the adult stage is an adaptation that has, so to speak, affected the younger stages in the course of evolution. If the changes are germinal to-day, we must suppose that they have always arisen in this way, although not all at the same historic moment unless one adopts the view of the inheritance of acquired characters. In other words, it is not improbable that the conditions seen in the flat-fishes to-day have gradually resulted from alterations of the germinal material of such a kind that in the course of time the asymmetry has become more perfect so that now the fish are better adapted to a bottom life. Kyle thinks that the flat-fishes are polyphylectic in origin, *i.e.*, this kind of change has occurred independently in at least four groups of marine fishes. Such a view, he states, is supported not only by comparative anatomy, as others had already pointed out, but also by the evidence from embryology, indicating that in each group the changes have taken a somewhat different course.

The most remarkable alterations are those involving the bones of the head, but these changes are always preceded by earlier ones in the head and body. In the skull the changes are "obviously due to pressure or stresses; apart from the tendency to grow, the structures are quite passive. The eye is not pulled into its new position by the frontals or its own muscles; it is demonstrably pushed over by the growth of the subocular ligament or the prefrontal. These, again, are constrained to grow obliquely by outside pressure. When rupture of the tissue is apparent, it is not due simply to the structures growing apart; they are definitely forced apart." Sinistral forms have almost invariably an air bladder lying more or less on the right side. Dextral forms have either no air bladder, or the air bladder more or less on the left side. "Throughout development, variations in the rate of metamorphosis can be judged by differences in the balancing conditions of the abdominal region."

Aside from the experiment of Cunningham ('91) on the effect of illuminating young flat-fish from below that had already turned to one side there is as yet no experimental work on these fish that bears on the question of their turning. In another group, however, the Amphibia, the asymmetry of the heart and digestive tract has been traced to a very early stage. There is also experimental work

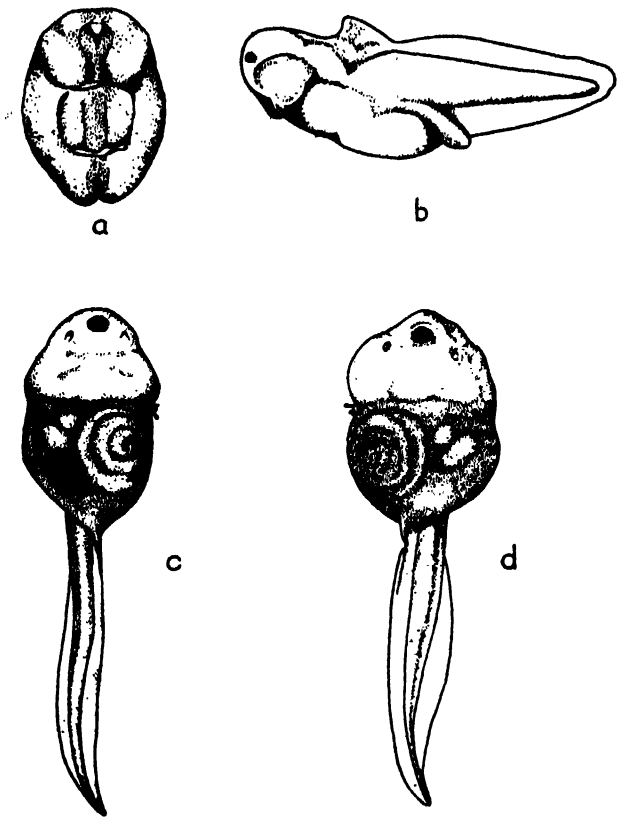


FIG. 1

that promises to throw some light on extraneous conditions that may influence the direction of the twisting.

THE ARTIFICIAL PRODUCTION OF SITUS INVERSUS VISCERUM

Spemann ('06) discovered that if a square piece of the neural plate of the embryo of the frog is cut out and is then turned around through 180° and replaced (Fig. 1, a), the position (situs) of the digestive tract (Fig. 1, c, d) and of the heart may be "reversed." Such a result was unexpected, since only a dorsal piece of the digestive tract was reversed, while the heart lies on the ventral side of the body. The result might be accounted for if the reversion of the digestive tract is first determined by the reversion of the dorsal piece and this influence affects secondarily the position of the heart. Spemann suggested, in fact, that the asymmetrical position of the liver, that arises at an early stage from the ventral wall of the digestive tract, might influence the direction of the blood that enters the posterior end of the heart in such a way that the direc-

tion of its twisting is affected. If the position of the liver is changed by the operation, the blood current might also be changed and bring about a reversal of the twisting of the heart tube.

The material collected by Spemann was turned over to one of his students, Pressler ('11), for further study. There were 19 operated embryos, three of *Rana esculenta* and sixteen of *Bombinator igneus,* the latter giving a tolerably complete series of stages. In order to determine what condition underlies the normal position of the viscera (situs viscerum) young stages were examined in serial sections. The first appearance of asymmetry is found in a stage where the digestive tract is still a straight tube. On its ventral wall, where its wide pharynx cavity narrows to become the oesophagus, an outpushing marks the beginning of the liver. Just in front of this, under the lower wall of the pharynx, the beginning of the heart appears (Fig. 2, a). At this time it consists of a straight endothelial tube lying between walls of mesoderm that havê opened out, right and left, to mark the beginning of the pericardium.

The liver rudiment projects a little to the right side of the middle line, and lies just behind the heart (Fig. 2, c). The intestine turns a little to the left side. The two large yolk-veins that open into the posterior end of the heart are present at an early stage. They are developing, in fact, while the changes outlined above have been going on. The left vein is larger than the right (Fig. 2, a), the smaller size of the latter being due, possibly, to the diminished space on the right side where the liver is pushing out. The pericardial cavities are also at this time a little asymmetrical. The right is slightly smaller than the left (Fig. 2, a). The mesocardium turns above and anteriorly to the right, behind and below to the left. This leads to, or is involved in, the slight bending of the endothelial tube leading through an S-shaped course to the anticlockwise spiral of the heart tube.

The embryos that develop after the operation (*i.e.*, after the reversal of the dorsal piece) show the following conditions. The dorsal fin does not gradually increase in height from its anterior end

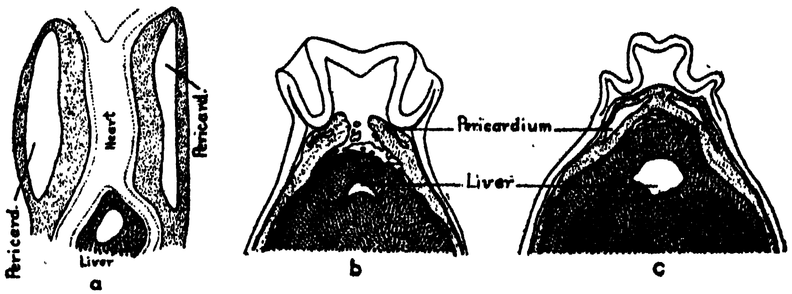


FIG. 2

to the tail as in the normal tadpole, but is broken in its course (Fig. 1, b), being higher at the anterior end of the transposed piece and lower at the posterior end where it joins abruptly the higher fin behind. Evidently the fin has developed as though still in its normal position. Similarly, the medulla and the chorda of the transposed piece, although continuous with the medulla and chorda of the embryo, change in size abruptly at the anterior and posterior levels of union.

The operation removed only the roof of the archenteron. The portion removed includes the part that becomes the dorsal wall of the foregut (duodenum) and the first part of the midgut and may include the region from which the dorsal pancreas is given off. This portion of the gut is then inverted, that is, it is expected to take the opposite turning from that taken by the normal embryo. This initial inversion in the anterior region may be expected to extend backwards throughout the rest of the digestive tract, into regions lying posterior to the inverted piece, provided its course is determined by changes that start in the more anterior region. In the operated embryo the liver pushes over to the left, instead of to the right, in the earliest stages observed, although its material lay far below the level of the operation. The dorsal and ventral pancreas unite, not on the right side, but on the left. In all Pressler's 15 cases, where situs inversus viscerum is present, the heart is inverted and this can be traced to its earliest stages. The right yolk vein is larger than the left and the heart bends to the left instead of to the right. Its spiral takes a clockwise turn. The inversion present involves even the finest details of structure, and, since the heart lies beyond the field of operation, its inversion must be supposed to be induced by changes that first occur in the region of the liver. Since one of the yolk-veins is smaller than the other, Pressler suggests that the consequent change in the direction of the blood flow may be the immediate cause of the inversion of the heart.

Several years later ('13) another student, Meyer, working with Spemann, made a larger number of operations of this kind. He examined in more detail the very early stages of the normal asymmetry and has made out a few further significant relations. His general conclusions also differ to some extent from those of Spemann and of Pressler. Meyer obtained eight cases of inversion (out of 9 operations) in Bombinator; 16 cases (out of 19) of *Rana esculenta,* and 6 of Bufo.

A study of the normal conditions in young embryos at a time when the first asymmetry could be detected showed that at the stage when the liver begins to turn a little to the right, the visceral sheet of mesoderm on each side of the endothelial tube of the heart shows also a slight asymmetry (Fig. 2, c). On the right side there is a

slight bend in the visceral sheet, while on the left side it takes a straighter course. The slight bend in the right side corresponds with the later bending of the S-shaped tube and beyond doubt is the first indication of future relations.

In these earliest stages the yolk-veins have scarcely formed and are not yet hollow vessels carrying the blood as they are a little later, and since at this stage there is no blood circulation, it appears probable that the bending of the heart tube can not primarily be due to the greater flow of blood from one of the yolk-veins.

Meyer found in the operated embryos (with an inverted neural plate) that the liver turns to the left and the relation of the right and left visceral layers is the reverse of that of the normal embryo (Fig. 2, b). These observations show that here also the asymmetry is very early initiated and is due most probably to the position of the liver. This, in turn, affects the visceral walls of mesoderm that extend over it and then forward to the heart region. It seems reasonable to infer that the differences seen in the two visceral layers, right and left, are initiated by the direction taken by the liver outgrowth.

Since at the time of the operation the mesoderm also extends under the neural plate and is inverted with the plate, it may appear possible that the mesoderm of the heart region may also be affected indirectly by this inversion. Such a view is rendered improbable by the fact that the dorsal inverted mesoderm lies behind the level of the future heart region, *i.e.*, it is not mesoderm lying on the dorsal side above the heart level.

Meyer attempted to find out by a critical experiment whether situs inversus is due to the inversion of the whole dorsal piece or only to the inversion of the dorsal wall of the archenteron. A square cut was made and then he attempted to lift off the neural plate (ectoderm) and the underlying mesoderm, leaving in place the dorsal wall of the archenteron. It was found impossible to leave the endoderm intact, but in some cases a large part of it (more or less torn) remained. The plate removed was then inverted and replanted in the opening. In five cases both digestive tract and heart were found to be inverted, possibly because enough endoderm had been left sticking to the inverted plate to cause inversion in the digestive tract. In three cases, on the other hand, no inversion took place, neither in the digestive tract nor in the heart, because possibly enough endoderm had been left to maintain the normal relations. The last result shows at least that the inversion is probably not caused by the action of the neural plate. It may be added that both Spemann and Meyer found that if the square plate after being cut out was not replaced, but the opening was allowed to close, no inversion took place.

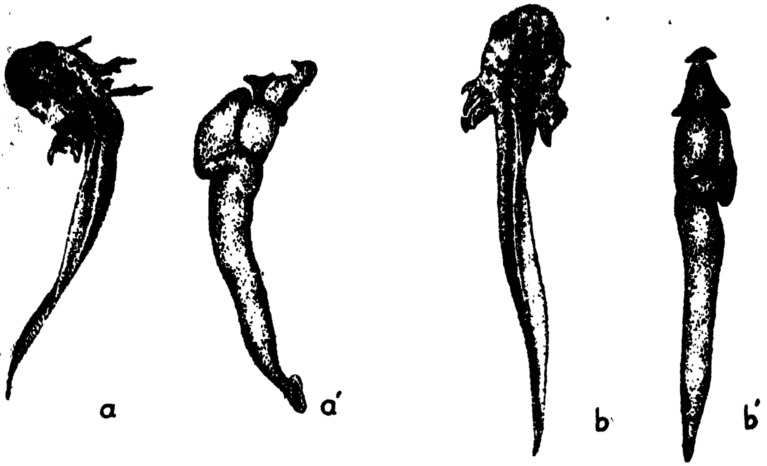


FIG. 3

The influence of the inversion on the position of the spiraculum was also examined by Meyer. In Bombinator it is ventral and median; in Rana and Bufo it lies in the left side. Spemann found that in one case the spiraculum was inverted when situs inversus was induced. In two other cases it did not unite across the middle line. Meyer found in five cases of situs inversus in *Rana esculenta* that the spiraculum opened on the right side (Fig. 1, d). This occurred also in one larva of Bufo.

There were a few cases in which inversion of the digestive tract was present, but the heart was not inverted. Such cases may possibly be due to the normal position of the heart having been already determined before the time of operation, so that while the inverted plate acted on the digestive tract, the heart continued to develop in response to the earlier influence of the normal relations.[2]

In this connection some experiments of a very different kind should be described that also bring about inversion of the digestive tract and heart. These results were obtained first by Spemann and later by Spemann and Falkenberg.

When a ligature is placed around the egg of Triton in the plane of the second cleavage and is then subsequently tightened so that the egg is constricted into two parts, either two whole embryos are obtained, right and left (Fig. 3, a, b), or one embryo with a double

[2] Mangold ('21) has shown that situs inversus occurs normally, *i.e.*, without operation, in about 2 per cent. of the larvae of *Triton taeniatus* and in nearly the same ratio in *T. alpestris*. When, in these, the heart is inverted the intestine is always inverted, but the liver or the intestine may be inverted and not the heart. Wilhelmi ('21) brought about inversion by removing a part of the left posterior side of an embryo when the neural fold was about to develop (one case in five).

anterior end (Fig. 4). When two embryos develop one or both are often defective especially on the "inner" side, but the results in regard to inversion seem to bear no direct relation to the extent of the abnormality. In 25 sinistral larvae both the heart and the digestive tract have a normal orientation. Only in one is the heart inverted while the condition of the digestive tract is uncertain. In 30 dextral larvae the inversion of the heart and digestive tract was clearly present in 12 embryos and probably in 2 others; the rest were normal.

Two other pairs may be added to the above list in both of which the sinistral embryo is normal, the right inverted. Other cases in which the halves remain partly united show sometimes the same relations. In 12 cases the left component was normal; the right, anterior region of the digestive tract was normal in only two cases; in the remaining 10 embryos the anterior part was inverted.

These results show that the inversion, when it occurs, is in the right-hand member of the pair. The cause of this is not evident. It does not seem connected with the incomplete development of the "inner" side that is shown by many of these larvae. Defects may be found in the eye or ear or in the musculature, or a limb may be absent on the inner side. If this one-sided condition prevails to some extent in the digestive tract and if the liver projects more to the more complete side (*i.e.*, away from the "inner" side) then this would be the normal direction for the right side, since normally the liver pushes more to the right, but it is these right larvae that show the inversion. The left larvae would be the ones expected to be inverted, but this is not the case. The explanation is contradictory to the facts.

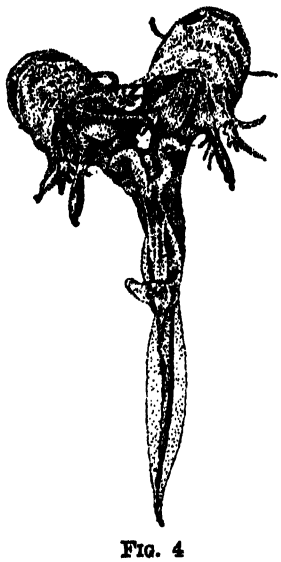


FIG. 4

Spemann inclined to refer the asymmetries of the normal embryo either to a primary micro-structure of the egg, or to some asymmetrical action of the sperm on the egg. But even on such an assumption it must be conceded that this "fundamental" structure can be readily inverted, as shown by the experiments. Since the double embryos are, when inversion occurs, mirror figures of each other and since this relation is not an uncommon accompaniment of paired whole structures, it might seem promising to refer the result to this general category, even although there is at present no adequate causal explanation of the mirror figure relation. But in the separated embryos the mirroring takes place when the parts are entirely separated. I am inclined to look, therefore, to some secondary condition imposed on the two embryos as a result of the deficiency on their inner side—a condition that supplements the initial steps already present in the left embryo, but which acts inversely on the conditions of the right embryo. For example, if the digestive tract and liver of the left embryo are displaced somewhat to the right (the inner or defective side) such a change is in the direction taken by the liver in the normal embryo and no inversion is expected. In the right embryo, a similar shift will displace the digestive tract and liver to the left (the inner or defective side) and such a change is in the opposite direction to that taken by the liver in the normal embryo and an inversion might result.

Other Cases of Inversion

The preceding cases, in which two embryos were obtained from a single egg, recall the double embryos (double monsters) that sometimes are found on the same egg. This is not an uncommon occurrence in fish embryos. In some of these cases it has been found, in fact, that the heart and digestive tract are often reversed in one of the embryos (Morrill '19, Swett '21). How far this result is due to the degree of separation of the two embryos and how far to a mutual influence of one on the other of such a sort that they become mirror figures of each other, as in cases of reduplicated limbs, will be considered in another connection.

The asymmetry of the aortic arch in birds and in mammals is another instance of asymmetry superimposed on a fundamental symmetry. The suppression of the right ovary and oviduct in birds may be connected with the turning of the embryo onto its left side at any early stage, but this relation has not been established, although it might easily be tested in those not infrequent cases where the chick lies on its right side. Dareste (1877) produced situs inversus in chicks by heating the left side of the egg (embryo) more than the right. The result has been confirmed later by Warynski and Fol ('84).

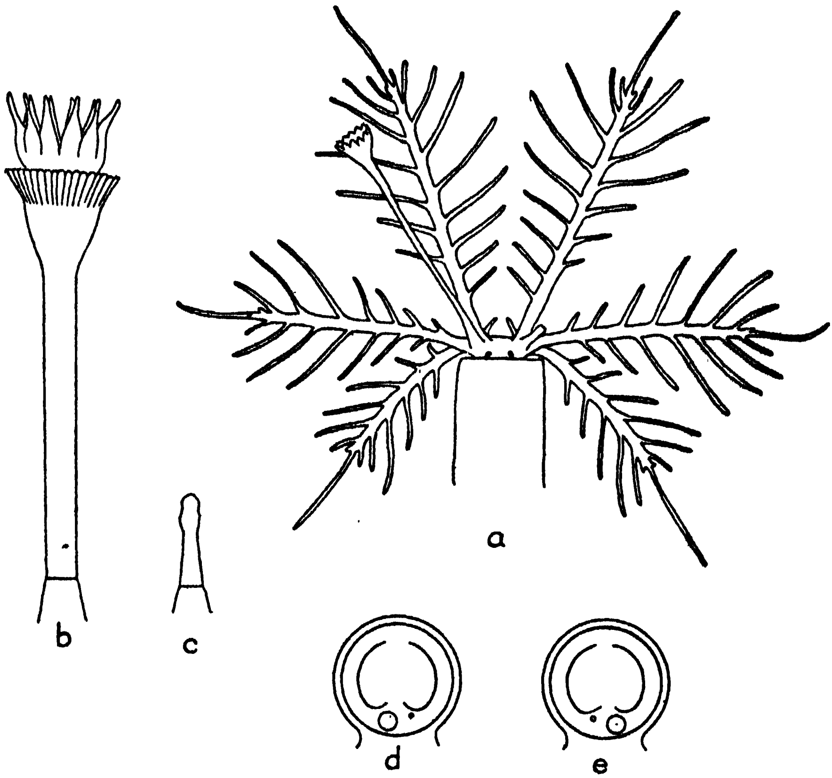


FIG. 5

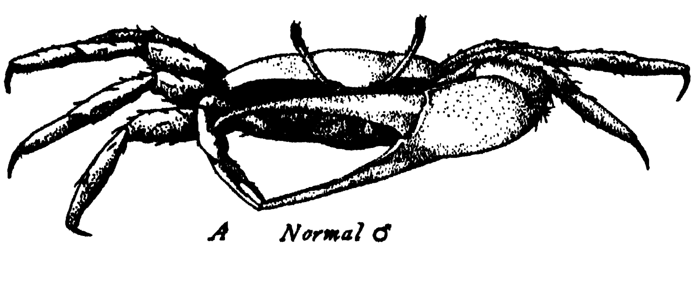
A few instances of situs inversus have been observed in larval sea urchins (Runnström '12, Ohshima '22) and in starfishes (Müller '50, Masterman '02, Mortensen '21). The pluteus stage of a sea urchin is normally asymmetrical; a functional hydrocoel being present only on the left side. In the reversed pluteus it lies on the right side. Several instances have also been described both in larval sea urchins and in starfish (Newman '23) where both a left and a right hydrocoel are present. Such larvae are symmetrical, standing as it were midway between the normal and the reversed condition.

The thread worm of the horse, whose eggs have a determinate and symmetrical type of cleavage, shows distinct asymmetries in the nervous system and in the excretory vessels of the adult, and these are typically on the same side. Zur Strassen found that about one egg in 40 has "inverse" cleavage, and that four adults out of 125 showed reversal. It seems plausible, as he points out, to assume that the reversed cleavage type gives rise to the reversed adult type.

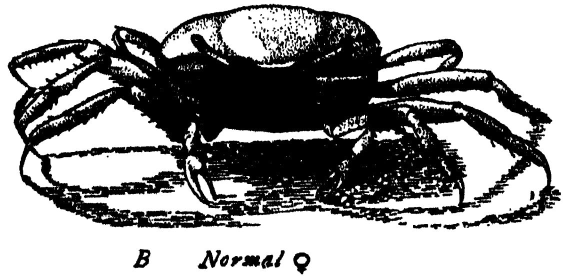
THE ORIGIN OF ASYMMETRY IN SERPULIDS AND FIDDLER CRABS

Some of the sedentary annelids, such as Serpula and Hydroides, have a sort of plug (operculum) that closes the tube when the worm retreats into it. The plug arises from one side of the middle line (Fig. 5, b). On the opposite side there is a tiny rudimentary plug (Fig. 5, c). Both represent modified gills of the young embryo (Fig. 5, a). Zeleny ('02, '04) has shown that if the large plug of the adult worm is cut off, the smaller one begins to grow, and in the course of a few weeks becomes as large as the one removed, and acts as the functional plug. From the stump of the original large plug a new, small plug develops. If now this secondary functioning plug is removed, the secondary small one enlarges to full size, and from the stump a small one develops, etc. This evidence indicates that the presence of one functional operculum holds its mate in check. The nature of this influence is not known. One is tempted to refer it to some material produced by the more developed plug that holds the other in check or by something used up by the larger plug that the smaller one needs to develop. Both of these views may, however, seem self-contradictory, since the influence imagined would be supposed to act in the embryo on both alike unless a threshold value is assumed. Since either the right or the left may be the functional plug, it would then appear to be only a question of chance which one got the start of the other. Such an interpretation would call for no contrivance in the egg to throw the balance to one side or the other.

The first pair of legs bearing the large "claws," of many crabs,



A Normal ♂



B Normal ♀

FIG. 6

FIG. 7

lobsters and other crustacea are different on the two sides and markedly so in the male fiddler crab (Fig. 6, A) and in the macruran alpheus. Here the larger claw may be either the right or the left one. There is no predetermined asymmetry. Once determined, however, it may be made to reverse in some species but not in others. As shown by Przibram, removal of the large claw of Alpheus leads, at the next molt, to its substitution by the smaller claw on the other side; but in other decapods, as in the fiddler crab, the large claw of the adult, if removed, develops again, and is not substituted for by the claw on the other side.

The development of asymmetry in the male fiddler crab (Gelasimus) has recently been worked out by Morgan ('21, '22, '23). In the youngest stages the two claws are alike in the male and female. In a later stage of the male both claws become a little larger than those of the female of the same age and show the swollen shape of the male "large" claw (Fig. 7, A). At about this time most of the young crabs lose one or the other of these "large" claws and produce at the next molt, in place of the one lost, a small claw like that of the small male claw or like the two small claws of the female (Fig. 7, B). This relation, once attained, becomes fixed, and even in young crabs no reversal after the removal of the large claw is possible. An accident, then, determines in this crab the first asymmetry of the claws of the male. There seems to be nothing in the egg or in the development that brings about the asymmetry. It is determined by an asymmetry traceable to an accident.

If the young male with two large claws is isolated and carefully protected from injury and fed, he usually retains both claws throughout successive moults and develops into a symmetrical male with two large claws. There are only two records of such adults found in nature, and since this occurrence is extremely rare, it might be expected that the loss of one claw, even at a somewhat later stage than that at which the loss normally occurs, is the event that generally leads to the asymmetry of the adult. In fact, experiments with very young males, that have retained both claws through two or more moults later than the moult at which the loss usually occurs, show that a small claw develops in place of the large one removed.

The converse experiment has also been carried out. Both claws were removed from young males with two large claws. At the next moult two small claws developed and in the two or three subsequent

moults both claws remained small. If this condition persists into the adult stage, a symmetrical male would develop with two small claws. A few such adult males have, in fact, been found (Morgan '22).

In a few cases where two secondary small claws were induced, as just described, one small claw was then removed. A small claw came back and the opposite claw also remained small. The induced symmetry has inhibited the individual from acquiring the normal asymmetry. In other words, when at the critical stage the individual has been led to take a false step, no subsequent rectification is possible.

Here, then, esymmetry is introduced, as a rule, relatively late in development. There is nothing in the egg responsible for the asymmetry unless it be the reaction system that responds at a cer-

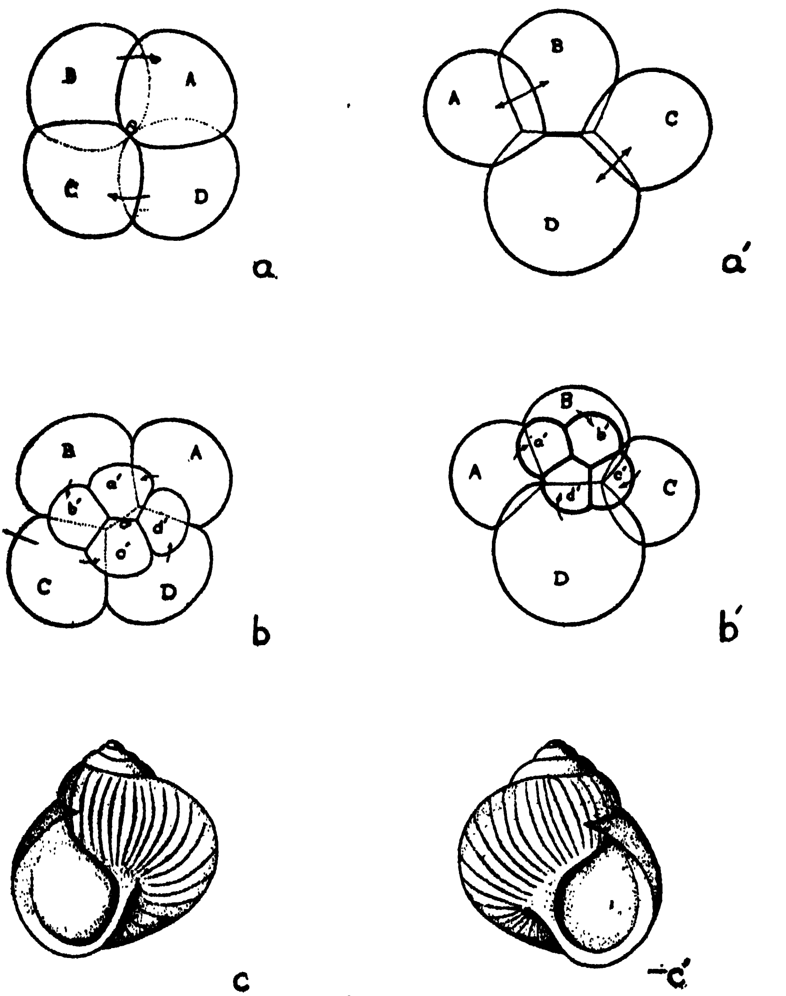


FIG. 8

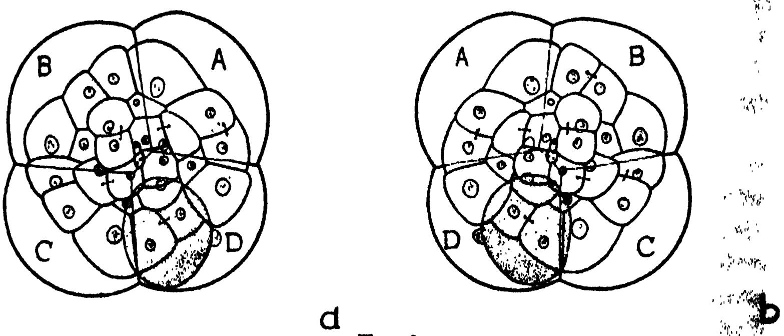


FIG. 9

tain stage in the development to an induced asymmetry. If in the young male crabs the right claw is lost as often as the left we can understand how it comes about that half the adult males have the right claw large and half the left claw.

THE ASYMMETRY OF SNAILS

In gasteropod molluscs the visceral mass on which the shell is moulded is twisted into a right- (Fig. 8, c′) or a left-handed spiral (Fig. 8, c). In some species, the spiral is typically dextral (Limnaea and Crepidula); in other species it is sinistral (Physa and Planorbis). Even within the same species there may be dextral and sinistral individuals. For example, some species of the Achatinellidae are typically right-wound (dextral), others left-wound (sinistral), but in some species both dextral and sinistral snails are found (Mayer '02, Gulick '05). Similar conditions are also found in Tahitian snails (Crampton '16). In several dextral land snails of Europe sinistral individuals have been frequently described (Lang '08, Hesse '14) and in certain localities reversed forms of several fresh water snails have been recorded (Dewitz '16, Boycott and Diver '23).

Crampton ('94) pointed out that the spiral type of cleavage is reversed in dextral and sinistral snails (Figs. 8, a′, b′ and a, b). In consequence of this relation, the mesoderm cell, 4d (Fig. 9), that is generally larger than the other members of the fourth quartet (4a, 4b, 4c), lies to the right of the first plane of cleavage in one type and to the left in the other (Fig. 9, the stippled cell).

The asymmetry has been traced to the position of the spindles for the second division of the egg (Crampton). It is further shown by the "cross furrow" at the meeting point of two blastomeres of the four-cell stage (Fig. 10, b′ b). As seen in Figs. 8 a and a′ the cross-furrow in the sinistral type (a) is the mirror figure of that in the dextral type (a′). In the dextral type (Fig. 10, a′), the right end of the spindle in the AB blastomere is higher than the left end

of the same spindle; and *vice versa* for the spindle in the DC blastomere. Since all later cleavage alternates between dextral and sinistral, Conklin ('07) suggests that even the first spindle may be dextral in the dextral type and sinistral in the sinistral type of cleavage. This has, however, not been demonstrated, although it seems quite probable.

At the third division of the egg four small cells are pinched off around the pole of the egg by a clockwise division in the dextral type (Fig. 8 b′) and by an anticlockwise division in the sinistral type (Fig. 8b). After this division a succession of small cells are formed from the four large cells (ABCD) by alternate anticlockwise and clockwise divisions. This continues until, at the seventh division, a large cell (4D) is pinched off from the large D-cell (Fig. 9). This cell, as stated above, is the first asymmetrical division in the sense that this cell (4D) is sometimes given off sooner and is often much larger than the corresponding cells of the other quartets. This 4d cell lies on the posterior side of the embryo and in the dextral type to the left of the middle line (Fig. 9, b)

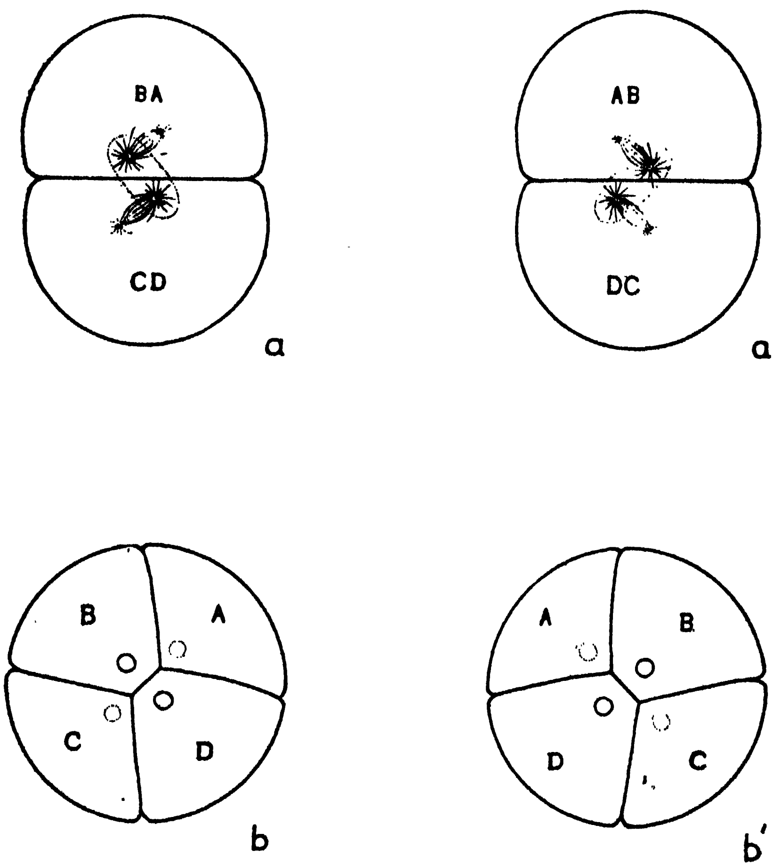


FIG. 10

which corresponds nearly to the second plane of cleavage. In the sinistral type the 4d cell lies to the right of the middle line (Fig. 9, a). The asymmetrical position of this cell from which the middle layer of the embryo arises suggests that the later asymmetry of the body is built up on this relation. On the other hand, the position of 4d may only be an expression of the type of cleavage and the latter rather than 4d itself may be the forerunner of the asymmetrical structure that develops.

Several attempts have been made to explain the spiral type of cleavage of the molluscan egg as well as the origin of the reversals seen in certain cases. Rabl ('00) called attention to spiral asters in certain eggs described by Mark ('81) and by Kostanecki ('96). He suggested that these spirals might indicate a spiral foundation in the cytoplasm responsible for the spiral cleavage, but later research has not confirmed these earlier observations as typical. In fact, the spiral aster is probably an artifact (Byrnes '99).

Conklin pointed out that if in snails having the right-handed spiral type the polar bodies are formed at the pole of the egg and the quartets are formed about the same pole, and if in the left-handed species the polar bodies are given off at the antipole and the quartets are also formed at the antipole, then the two types would show reversed spirals if these depended on the same fundamental spiral structure in the cytoplasm. Conklin has himself called attention to the difficulties in making such an interpretation, and there is no evidence that the poles are reversed in the two types of eggs, and much evidence that they are not.

Holmes ('00) suggested that if the first cleavage of the dextral form corresponds to the second cleavage of the sinistral types this would account for the reversal of the spirals. At present there is no evidence of such substitution. The only advantage that such a view might offer would be that the spiral structure of the protoplasm, if such exists, might be assumed to be the same in both forms.

It may seem hazardous, in the light of these difficulties, to attempt at present to suggest a solution of the two types of spiral cleavages leading to the final asymmetry of the snail, were it not that in one respect at least we have recently made a step forward. The genetic evidence indicates that the twisting is inherited as a Mendelian character, and is, furthermore, a special case of maternal inheritance; it follows that the character is impressed on the ovarian egg before the polar bodies are extruded. Two possibilities are then given; either the influence is exerted from the egg-nucleus before its maturation divisions, or else it is determined by the follicle cells of the mother that surround the egg during its growth. The former alternative offers no further clue as to how the cytoplasm is affected; the latter alternative might appear to offer a solution. For example, if the polar region of the egg were

supposed to be oval in shape (as a result of the influence of the follicle) and if in the dextral type the oval is turned to the right (Fig. 10 a′) and in the sinistral type to the left (Fig. 10), and if the position of the two spindles at the second division is determined by this polar field then it might appear that the differences in the two types could be accounted for.

On the other hand, there are some obvious difficulties for this interpretation. It must be supposed, for instance, that in a snail that is actually sinistral (owing to its maternal inheritance) but genetically dextral, the latter influence, and not the form of the twist, determines the character of the egg. In the second place, it has been shown by Wilson ('04) in the mollusc Dentalium whose egg cleaves spirally, that fragments both of the upper and of the lower hemisphere cleave spirally in the same way as does the whole egg. Such a result is inconsistent with the assumption that the spiral is due to an influence starting during cleavage from the polar field. It might also be urged that the dextral type of cleavage is present in forms like Nereis that are themselves bilateral; but this is not perhaps a serious objection, since it is not the shape of the individual that determines the twist, by hypothesis, but the genetic make-up of its cells.

Under these circumstances it is apparent that the hypothesis suggested above is entirely inadequate. The situation, as it appears at present, may possibly be stated as follows:

(1) The genetic evidence indicates that the type of cleavage, dextral or sinistral, is inherited probably as a Mendelian pair of characters. Furthermore, the inheritance appears to belong to that category of cases known as maternal inheritance.

(2) Since the characteristic type of cleavage is shown by fragments taken from any region of the egg, it is not probable that it can be traced to any localized structure on or in the egg, but is a peculiarity that develops in the protoplasm at about the time of fertilization and need not be supposed to be present as such before this time.

(3) It is not necessary to assume that this peculiarity is expressed as a spiral structure in the protoplasm. There may well be other influences that turn the first spindle in an oblique position with respect to the primary axis and at the same time direct the spindle in the clockwise (or anticlockwise) direction. The later reversals of the cleavage may be due to the orderly sequence of the succession spindles at right angles to the last ones (or possibly also to the form of the preceding cells). This view avoids the difficulty of assuming that the influence, that gives the first spiral, reverses itself at each subsequent division.

We need at present critical experiments to test these and other

possibilities. By compressing the egg, by studying the cleavage of fragments of sinistral types, or by altering the conditions of the egg in other ways, it should be possible to discover the nature of the protoplasmic factors that determine the spiral cleavage pattern.

Finally, since the position of the first cleavage plane is not predetermined, either in the bilateral or in the spiral types, it follows that the median plane of the embryo may coincide with any meridian of the egg. Therefore, whatever the nature of the conditions that lead to a spiral cleavage they carry with them the condition that locates at the same time the bilaterality of the embryo. The two must, I think, be regarded as part of the same process.

THE NEED OF INTEGRATION OF ATTITUDES AMONG SCIENTISTS

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THE difficulty in getting the masses to understand and to react consistently to modern science seems to some disheartening. When educational and governmental experts, health boards and, in general, the applied technicians are handicapped in executing their programs to apply science among the masses, they wonder at the social inertia which they encounter. One must not overlook, however, the disconcerting fact that very often among scientists themselves is found the most curious mixture of modernism in a specialized field coupled with an intense adherence to some medieval or primitive superstititon which is unworthy of them. The inertia against change exists in us all, but if we can give men of science a training which, among themselves, will aid in producing an integration of attitudes towards the total contribution and cultural meaning of science, we shall have another force to strengthen our attack on ignorance, traditional taboos and pseudo-science with their attendant controls of the man in the street.

Before discussing the present education of the scientist and offering suggestions for improvement, it will be necessary to trace briefly the fundamental bases of personality upon which the integration of attitudes rest.

Beginning with the behavior of simple organisms and going up the biological scale to man himself, we find an increasingly complex integration of behavior patterns directing the action of the total-going organism. In man and the mammals, particularly, this reaches an exceptionally high level through the complex development of the brain cortex.

While synthesis of part-processes of activity into total behavior is common, there also lie in us the roots of dissociation of these part-processes from each other. In fact, the new conditioning which goes on in learning is partially a procedure which involves the disintegration of old habits and the formation of new. We all possess trends which lead to the development of antagonistic sets of attitudes and habits, quite as much as trends in the opposite direction. In certain skills, automatic writing and kindred phenomena are seen extreme features of what is common to all in minor ways. Furthermore, the same possibility of integration, or its opposite, lies in the realm of ideas as in that of motor responses. One

easily recalls persons whose attitudes are quite as dissociated as motor processes may be. These are the persons of "compartmentalized" types of conduct.

Dissociation tendencies arise from two principal factors, among others: (1) the nature of the individual's ideas and attitudes which rest, in part, upon his emotional-instinctive background, but which lie especially in the field of fundamental behavior patterns laid down in the early years of life, and (2) the diversity of stimuli, that is, the differences in environmental situations in which the personality grows up. It is obvious that the diversity of stimuli possible is correlated throughout development with the diversity of response-systems. The primary external stimuli to which the individual reacts and around which his "values" grow up are found in the family, the playground, the school, the gang, the church, the business and industrial groups, recreational situations, including responses of sexual nature and the very important group of objects and situations which involve sensory-perceptual explorations and manipulation.

The question, then, is how to integrate these conflicting trends into a working whole, not necessarily attempting to make the entire personality revolve around one small item, but correlating the various trends so that they operate in a harmonious synchrony for greater effectiveness and more complete response.[1]

The problem of the scientist is a part of this same cloth. It is frankly evident in the fact that the present-day man of science is, on the whole, unable or unwilling, because of paucity of training, to try to see his problem in perspective.

Science had its roots in philosophy, which for long periods remained under the dominance of the deductive rather than the inductive method. But even the older philosophy had the virtue of emphasizing the integration of knowledge and life activity. But much of what is now considered of greatest importance in science is the outcome of the empirical attack of men on specific phenomena which the older philosophy ignored. It is natural that modern science should more and more move away from the older philosophic position to one of individual studies upon isolated problems, correlating results and bringing in generalizations only as they seem apparent from the data.

[1] The integration of personality, the writer believes, is closely bound up with the notion of completeness of response in the organism. *Cf.* J. Peterson: "Completeness of response in learning," *Psych. Rev.*, 1916, XXIII, 153ff; also, his "The functioning of ideas in social groups," *ibid.*, 1918, XXV, 214ff. For the acceptance, in part, of this idea by certain philosophers, *cf.* R. B. Perry, "Docility and purpose," *ibid.*, 1918, XXV, 1ff., and E. B. Holt, "The Freudian Wish," 1918, especially "Appendix."

The individual, in reference to the presuppositions of modern science, can be described for our purpose under a doctrine of attitudes. The scientific frame of mind is nothing but a system of attitudes, ways of looking at phenomena, largely non-conscious in the adult worker and produced by years of training. That which distinguishes a scientist from the common man is not only the stock of information and technique which the former possesses, but quite equally the "mental set" through which the former looks upon the world. The recency of this scientific attitude is one of the significant facts in "intellectual history."[3] Even the average scientist does not realize the profundity of meaning science may have for future culture and conduct. It is the hope of the technician that the results of science may spread more and more into human life and behavior, replacing the superstitions, rationalizations and ignorant controls of the past for the predictable and ultimately humane controls of science and ethics. Science is man's contribution to himself, in contra-distinction to the benefits of nature. Whether the individual worker in science agrees or not, the broader view must realize that the applications of science should relate to social, that is, ethical ends. Whether but a part-process of science, as it were, and not its entirety be given to benefit man depends largely upon the integration of the scientific with the other attitudes:—moral, esthetic, religious, political and economic—resulting in a synthesis of the whole for social and individual enhancement.

The following not uncommon case will illustrate the general meaning here. The writer is acquainted with a brilliant natural scientist whose training was the best which this country affords. His doctor's thesis was considered an exceptional contribution and won him a *summa cum laude,* the first ever given by his particular department. His dissertation was translated into both German and French within a few months. This man is to-day employed in research of importance, and it is but a step from his own field to that of philosophy. Yet this specialist, in spite of his training and position in a highly technical field, is distinctly medieval in his attitudes on religion, political science, economics and biology. He gives aid and comfort to the sort of organizations which dismisses men from its educational institutions for belief in evolution, has himself been known to speak "with authority" against the theories of modern biology and to defend the most ultra-reactionary political movements. This is frankly an extreme instance. It illustrates, however, the problem under discussion. One does not expect any man to be an expert in every field. The point is more that this person, while

[3] *Cf.* James Harvey Robinson, "The humanizing of knowledge," *Science,* n. s., June 28, 1922, LVI, 89ff.; also, "The Mind in the Making," 1921.

possessing an important place in his own field, is lacking in that all-valuable matter of general perspective. Before expanding the implications of this type of mind, let us look at the present educational regimen to which the young man of ambition for science is subjected and at the arena of action, too, in which most scientific work is done.

At the outset it must be recognized that the recency of science has prevented its reaching into the earlier training of the average pupil. Our elementary schools are still proceeding in large measure upon the traditions of previous centuries both in method and material. The basic education of many present-day scientists was totally unsuited to their later work. Nevertheless, in the breaking up of the curricula into differentiated systems and, especially, in the project method of teaching, do we get glimmerings of what may become universal. The lamentable fact remains that the usual elementary and high school teacher is poorly prepared to give and encourage the scientific attitude and technique. Often enough the individual teacher has fairly adequate training in his special field, but lacks that important background which we shall indicate. Furthermore, the methods of presenting science in elementary and high schools are antiquated. The student is not invited to take the standpoint of a searcher after facts, but is taken on informational excursions into intellectual museums where various unique and often disconnected exhibits of man's endeavors and discoveries are paraded. If any questions are answered it is usually in the manner of a tourist guide to ignorant sightseers: dogmatic and not infrequently incomplete information, to say the least. The significance of the project method lies in this. It inducts the pupil into a problem of his own initiative and the progress stimulates him on, the teacher remaining one giving direction only at critical points, and above all maintaining before the pupil, even in the simplest study, the standpoint of a seeker of truths, not a dispenser of a new sort of "divine" information.

Couple with this incompleteness of the typical public school science teaching the additional fact that everywhere the older and more orthodox elements in the community insist that too radical ideas shall not be given the pupils, lest they lose faith in the traditions and mores that the group-elders approve. To many persons this whole interpretation is very questionable. Many believe that the proper synthesis of science with other materials taught in the schools can be made, and that, moreover, even children, certainly those approaching the high school age, can be given some concrete cues to the interrelation of science and conduct.

This fear of introducing the young into the sciences, especially

biological and social sciences, before they get into college has a disastrous effect upon the later training in the college or technical school. Take evolution as a convenient theory of biology, or take the much discussed matter of American history teaching. In the former the theologically conservative groups frequently dominate in direct and indirect ways the teaching of science in the public schools. The writer knows of many cases where school boards specifically inquire of the candidates for science positions in high schools whether they teach evolution and whether they are members of a Christian congregation. He has in mind one community where an instructor in biology in the town high school put to rout a vigorous ministerial attack on his teaching through an appeal for support to the more liberal and modern churchmen of the state by a series of letters explaining his fight for freedom in his school. Too often, likewise, the teachers of American history are under pressure to conform to the politico-economic conservatism of a given community.

We have, then, from the side of preparatory training, often a mass of excellent factual material, but no integration. The boy or girl knows the rudiments of biology, chemistry, physics, economics and history, but he does not know the first steps of what they mean in cultural progress, in relation to the entire body of science and especially their meaning in relation to social conduct.

In both high schools and colleges we usually find an attitude expressed as follows, if any thought has been given to the matter whatsoever, "Give the student the facts. That is all. They will do the rest," implying that the students have the capacity and inclination to integrate their materials on higher planes. This notion is undoubtedly fallacious. The ability to integrate separate facts and modes of behavior is extremely difficult to induce, as every teacher knows. The inclination to relate the various branches of science to each other is very little encouraged or even thought of. Certain general science courses are a feeble effort towards an alteration in the traditional methods. It is often too late to try to bring about such a desirable viewpoint in a graduate student, when all his previous education has been so dissociated.

As William Graham Sumner said, "Primitive man did not philosophize. That is our way, not his," so, too, the entire matter of integration is one of habit and training, quite as much as technique-learning. No doubt there are many men who are essentially workers with details; they spend their efforts on the minutia of science and "never see the forest for the trees." Perhaps these men can not reach high levels of integration. These men have been described by a man of reputation in science as "highly skilled workmen with

a refined trade." One wonders, nevertheless, what other attitudes these men might take had their early training been otherwise. Is not the matter partly a question of the primary direction of attention?

When the freshman arrives at college his scientific knowledge is crude and disorganized, and his general patterns of mind are those laid down by the mores of the community. His science remains essentially a thing apart. Religious, economic and other superstitions are in control.

Specialization in modern science continues this lack of perspective in college. The average student plunges *in media res* into some special branch, in terms of real or imagined aptitude and interest. He follows the hints and regulations of a major department. Often the rules of the game necessitate a very fixed procedure. True, the line between the branches of the natural sciences is not severely sharp in the first two years of work. Modern biology, chemistry, physics and mathematics tie up closely together in background. The social sciences, on the other hand, remain quite a distinct group, and there is very little attempt to dovetail these together or to relate them in any way to the natural sciences.[3]

The specialized laboratory is the greatest advance which the pedagogy of science has brought us, yet it is not enough. A step forward may be initiated through attempts, in the early college years, at symposium courses in the sciences.[4] But for men who are going into science for their careers there is great need in the senior college and graduate years of training in the methodology of the sciences and the relation of science to living and conduct. In the scattered institutions where such courses are offered the students who should have them most do not register for them. This was the case with the example cited above. The brilliant candidate for the Ph.D. in science worked out his thesis in a laboratory not two hundred yards from the building in which an extremely able philosopher, with good training in natural science also, offered courses in the logic and methodology of the sciences.

[3] Under the leadership of President R. F. Scholtz, Reed College, Portland, Oregon, is trying a very progressive program of building the entire college curriculum around the idea of uniting the sciences and the humanities. The courses in literature, anthropology, psychology and social sciences are through the nexus of cultural history brought into relation to mathematics, physics, chemistry, biology and other natural sciences. This unique effort may prove a valuable educational experiment.

[4] At certain institutions, as at Stanford University, symposium courses in the sciences have been arranged for freshmen and sophomores. These have been worth-while, but there still remains little recognition of the fact that we require also some conscious linking up of the meaning of science, *in toto*, with the cultural values and conduct of the world.

The general training in English universities has many advantages. It is not only a matter of the courses themselves, but a feature of the cultural atmosphere. While the situation in British institutions is not perfectly adjusted, it is a distinct improvement over our own, where the influence of German specialization, abetted by the American business folkways, emphasizing energy and application, makes against the air of discussion and the perspective needed to foster the true synthesis of specialty with cultural values.

It is not to be understood that the student should give himself over to system-making, to philosophizing upon the relations of the fields of knowledge and thus destroy his inclination and energy for careful work on technical problems. What is desirable and perfectly feasible is a minor revamping of the training to include the things just mentioned: general methodology, interrelations, certainly the limitations of the specialities and lastly their nexus with human life. It has been the good fortune of the writer to be associated with students and professional men of different sciences and with men of literary and artistic activities. In probing their ideas and attitudes for synthesis and integration, he has discovered that in those few where it is found, it has come about in chance ways, by contact with a particularly able scholar (as well as specialist), through reading, occasionally by contact with fellow-students. Very seldom is the viewpoint the outcome of a common thread of significance running right through all: science, art and life.

The net result of the present system of specialization, therefore, is the lack in general viewpoint concerning the meaning of science in the large and its relation to the humanities and to life outside the laboratory. Even though the average hard-headed scientists are apt to be "anti-metaphysical," as they proudly put it, too frequently this notion leads them into the most naïve types of metaphysics of their own without their being aware of it. While the writer would not push the need for training in general philosophy, he would suggest that the historical connection of science and philosophy ought to be considered and an effort made to once more relate them. At any rate the basic foundation which we are advocating here is necessary. An awareness of the methodology and limitations of science in general would correct many of the sharp angles of difference between related sciences, for instance, between physics and chemistry on the ultimate nature of matter, or between psychology and physiology over their scope and interpretations. An example of the present status of attitude in regard to this matter is in point.

At an active state university a year or so ago, two or three of the younger faculty-men in the natural science group became mu-

tually interested in the problems of the logic of science, the overlappings and limitations of the various fields. This interest grew, in part, out of a discovery that their own training was lacking in just this matter. Believing that their colleagues in related disciplines would be interested in similar questions, they proposed to the Science Club (an organization of faculty men and women in the natural sciences) a series of meetings dealing with papers and discussions of the fundamentals of science. One not acquainted with the usual attitude in the academic world can scarcely believe that out of a group of nearly forty men and women, practically all of them having the doctorate, only a very small minority showed any interest whatsoever. The president of the club, reasonably well known in his own specialty, was even strongly opposed and in no mild sarcasm remarked that the important matter for every one was to apply himself to his own problem. It was no concern of his what connections or contradictions might occur in reference to related fields. The need of investigation the advocates granted. They were proving their faith by their own research. What they could not grant was the notion that there was no necessity whatsoever of discussing conflicts, contradictions, of taking stock of scientific meaning in-the-large and its place in the cultural ongoing. It is said that the major students of the president of the club illustrate unfortunately the common lack of perspective and consequent confusion in the interpretation of their research.

When one recognizes such an attitude in men of science, what may one hope for in the way of integration in the high school instructor, applied technician and the common man? Again, the example may be unusual, but it throws into relief a common seriousness. The same sort of question was implicit in a recent discussion of a group of psychologists over the type of training for candidates for the doctor's degree: extreme specialization versus broad, general culture, including some technique, of course, or a combination of the two which would produce a human being as well as a machine for turning out research.

The requisite is a balance between the two tendencies. The tremendous growth of the sciences has swept us off our feet. There is some danger in over-specialization, not so much for the general results on paper, as upon the personality of the man. There is more likelihood of dogmatism in science from high specialization, both as regards the assumed importance of one's own field, and from the equal absurdity of "particularistic" theories to account for very complex phenomena. One needs but mention current Freudian psychology with its one instinct, behaviorism with stimulus-response, in anthropology, Lippert's famous theory of the inevitable

correlation of domesticated milk-giving animals with high culture, the large number of single-track theories in sociology and so on. To counteract this extreme there are at hand cultural history, history of science, philosophy and the humanities, giving all together the only proper center around which one's personality and hence one's speciality may turn.[5] The very size of modern science is discouraging, but the fact ought to stimulate rather than inhibit us in the attempt to gain systematic orientation for our students and for ourselves.

Turning from the educational aspects of the topic to those bearing on the public mind, we see another set of forces arrayed against synthesis. In the relation of the scientist and the community the powerful factor of prestige comes into play. Men recognized in their own fields are under the constant temptation to offer their advice on the world in general. This arises primarily from the psychological effects of felt-recognition. The seeds grow rapidly in every one to speak as one having authority. Secondly, the populace, encouraged by the press, looks upon the man of science as a present-day miracle and magic worker. A headline reporting the lecture of a psychologist on abnormal psychology is likely to phrase it in terms of the occult and the mysterious. Sumner pointed out how quickly the masses retouch the scientific notions to suit their own mental set.[6] In view of this the newspapers and their clientele are apt to turn to the men of science in a given community for opinions, not only in their own fields, which are often too remote or abstruse for the ordinary person to grasp, but frequently on matters of the day. Some men of reputation unfortunately take the slight place of newspaper notice too gravely. It means recognition in one's own neighborhood, a thing few scientists have or should much concern themselves with. The social pressure is effective. As a consequence we find Professor X or Y, a specialist, in a remote branch of natural science, quoted in the papers for opinions on law Bolshevism, and Margaret Sanger.

Examples could be multiplied. In the social sciences the danger is peculiarly present, since every citizen, in this country at least, considers it almost a duty, if not a right, to speak on every conceivable subject which touches the body politic. Hence a natural scientist or engineer may regale a business men's club with a discussion on economics, on the errors of proportional representation or a defense of the Open-Shop. Some wonder when a professional politician makes an unscientific analysis of an international banking

[5] *Cf.* H. E. Barnes, "The historian and the history of science," The Scientific Monthly, 1920, XI, 112ff.

[6] William G. Sumner, "The Folkways," 1901, p. 47.

situation, but they should marvel more when a natural scientist, say, speaks with arrogant authority on social questions.

Most scientists, it must be said, are suspicious by sad experience of newspapers and desist from comments therein. More frequently men who are technologists and inventors of mechanical devices take to general press publicity and subsequent prestige. To the ordinary person men like Edison are far more important than Michelson and Einstein. The inventor is naturally nearer the folkways; he deals with more or less understandable stuff.

In short, there is a common tendency to universalize authority, both among the followers and in the assumption of authority by experts, executives, religious, political and military leaders. The mass of mankind desires an element of omniscience in its authorities. The populace demands an "all or none" principle. It protects them from doing any thinking for themselves; all that is needed is reference to authority to settle doubtful questions. This dogmatism the scientist ought to resist. Even though the application of scientific principles means predictability and control, it can not mean absolute finality. The progress of science is a continuing process. There can hardly be a staticism, though there may be a reduction of our present acceleration. Only the ultimate limits of man's mind can stop him from stepping forward in the conquest of the universe. Scepticism, as Veblen well says, is the essence of the scientific mind. We recall Abelard's famous dictum: "The beginning of wisdom is found in doubting; by doubting we come to the question, and by seeking we may come upon the truth." The attitude to change one's attitude is invaluable.

Another serious handicap to the scientists themselves is for a man renowned in his own field to throw the weight of his authority towards some pseudo-science. This is illustrated by the interests of men of prestige like Alfred R. Wallace in spiritualism. More recently the movement termed "psychic research" is in point. Men like William Crooks, the chemist, J. H. Hyslop, the psychologist, and Sir Oliver Lodge are heralded as "authorities in science" for this popular vogue.

While the purpose here is not to make dogmatic implications about immortality, one way or another, the fact still remains that, measured by our present criteria in chemistry, physics, biology and psychology, the evidence for the alleged findings of psychic research causes us to hold in abeyance any authoritative pronouncements for the same. The facts of the psychology of testimony, the questionable experimental controls, the whole tremendous effect of "mental set" in producing illusion,[7] the extreme amount of fraud,

[7] The historic case of the N-ray in physics is an example of what a "wish" to see will do to a group of men working in a narrow field. *Cf.* O. Sackur, "N-Strahlen: Ein Beitrag zur Psychologie des wissenschaftlichen Beobachtens," Beitrage z. Psych. d. Aussage: 2; no. 2: 147–154.

conscious and non-conscious, which has been uncovered in asserted demonstrations, especially the relation of "results" to the abnormality of the individuals performing, and so on *ad infinitum,* make the legitimate scientist dubious of the entire matter.[8] The likelihood of destroying the faith of millions of people in the persistence of life after death is infinitely remote if pragmatically desirable. So long as these beliefs do not handicap the highest sort of living, here and now, we may imagine them harmless. It is when they obstruct the enhancement of human life and values through the applications of natural and social sciences that we must consider them a difficulty. It is because they, more or less, tend to block and obscure scientific application, particularly by giving the masses a wrong impression of science, that the lent prestige of a scientist to spiritualism and its ilk is serious.

In some sections of our country health work in the public schools has been in great jeopardy during the last ten years through the activity of certain sects opposing it on the ground of religious belief. In this particular instance men and women of wealth and position in the economic world are prominent protagonists against health inspection and remedial measures. These people bear much prestige in their communities. Let a man of science, even if remote from medicine—in fact, some remoteness of interest actually enhances his importance in their eyes—but speak against this hard-won movement in our schools and he is haled as proof, scientific and absolute, of the standpoint which the religious doctrinaires so firmly hold. The same thing may be said of the fight over vivisection. Some men of standing in certain communities, whose judgment should have led them to more sensible views, have given support to the sentimental and idle men and women who go up and down the country bewailing the "terrible" treatment of dumb animals in our experimental laboratories.

The scientific attitude is rare. The history of man has paralleled, in a sense, the growth of objective attitude. It demands a high development of intellectual powers. For it to touch the entire person, it requires also a high synthesis of the specialized knowledge with the rest of the personality, especially in relation to emotional attitudes on questions where other scientists may be experts, for instance, in reference to social beliefs held dear in the community. The scientist whose whole personality is so integrated is rarer than he with objective attitude in a given specialty and in this way the former comes nearer the great artist, writer and philosopher. Part of the difficulty is due, as we have seen, to the education which

[8] *Cf.* J. E. Coover, "Experiments in Psychic Research," Stanford Press, 1917.

the usual scientist receives, part of it, no doubt, is related to temperament. Some men really seem incapable of escaping a mild type of dissociated living and thinking.

We have spoken of those cases where men of science drift into easy authority in remote fields. Nearer home to most of us is the fact that the intense specialization to-day has robbed men in closely connected fields of the contacts and relations previously held essential. The psychologists know fairly well their physiology and neurology, but little of sociology, which is important when dealing with the social behavior of the individual. The sociologists, on the other hand, know their psychology and biology but meagrely. The economists, political scientists and historians, with brilliant exceptions, know as yet practically nothing of physiology, psychology and sociology. The field called "Education" illustrates particularly the need of training in a number of related fields. To many persons it is unfortunate to see a trend in certain "schools," "colleges" and departments of education towards an inbreeding of their own curricula, under the notion that they can give their students all the training their specialties require. Education must remain secondary to other sciences, and if it is to maintain a vitality, it must keep close to them in preparing its men and women. What can one do in "education" who does not know his biology and mathematics, his psychology and sociology, at least?

Among natural scientists the principal handicap is the divorcing of their technical interests from the ordinary course of living. They lack perspective in reference to the social sciences and in toleration of experts whose knowledge leads into the field of human behavior.

One does not deny the immense pressure which specialization has put upon us all. Once homogenous fields, like chemistry or biology, are now too large for one man to cover adequately. We have indicated above some means of overcoming the problem in the training-stages of scholarship. The fundamental need is a new set of attitudes in the scientists making for well-rounded orientation. Their science in one sense must become an art, it must grow out of an intense personal adherence to the truth, coupled wth toleration and caution regarding types of reality where they are not themselves experts. Before concluding with an implication for social progress, there are a number of features of our present habits of scientists that need emphasis:

(1) There is a certain amount of false stimulus among scientists, in this country particularly, to publish, to get into print. There is almost a research psychosis with some men, which, like all psychoses, dodges the reality of more serious, long-time effort in the attempt to make something immediately publishable. This situ-

ation arises from our academic institutions in large measure. Advancement in position, with resultant betterment of economic status, is closely bound up with the number of papers and books one has to his credit. Then publication, no matter what sort, seems to enhance prestige with colleagues and students. This mistaken emphasis is very likely to encourage shoddy work, and journals in which one may put forth his work may be quite as much a sort of mild curse as a blessing.

(2) We need stimulation to read science in general and the inter-relations which are emphasized in such periodicals as *Isis*, *Science Progress*, *Scientia*, *Science* and THE SCIENTIFIC MONTHLY. There is need just now for a *rapprochement* of the natural and the social sciences.[9]

(3) One fears that the "Ph.D. Octopus," which William James so succinctly described, is in a way to strangle us. The large quantity of mediocre results which comes from men and women rushing through the graduate schools in mad striving to secure the coveted title is disintegrating. Importance is put on having the degree in order to get a position in the colleges or universities throughout the country, not as a badge of patient and outstanding accomplishment. This tendency produces a "set" for quick work which a different emphasis would correct. Many of these people possess ability far above that illustrated in the work they do, but the habits inculcated often prove disastrous. The attitudes formed in the three or four years of graduate work tend to outlast a much longer period thereafter.

(4) Our democratic ideals have had a curious way of producing uniformity rather than diversity in research interests. In France, we have been told there is far greater encouragement of individual initiative in research on the part of the student.[10] In this country there is a very grave tendency in the opposite direction. Reward is put upon conformity, that is, agreement in problem and results with the interests of the man with whom one works. Investigation to examine the fundamental assumptions of one's major professor is discouraged or actually suppressed. The result is a kind of rigid discipleship, almost an intellectual sycophantism, which is difficult to overcome. On an occasion of a dinner tendered Professor Jowett by his former students, he remarked that the greatest compliment ever paid him was that of a considerable number of able scholars whom he had trained not one of them agreed with him. One wonders sometimes if the spirit of conformity in research is not a

9 *Cf.* Robinson, *op. cit.*; also, W. M. Davis, "The reasonableness of science," THE SCIENTIFIC MONTHLY, 1922, XV, 193ff.

10 P. Boutroux, "Science in France," THE SCIENTIFIC MONTHLY, 1921, XIII, 435ff.

phase of the wider standardization and mechanization of life in the modern age.

(5) Most of the men who receive advanced training in the sciences are not properly classified as scientists at all. Their work, however, brings them close to the interests of research. These are the applied technologists, ranging all the way from the usual medical practitioner to the electrical or chemical engineer. All these should maintain some interest in the perspective of their work in the social-economic world in which they live.[11] The ignorance of allied fields is illustrated by the movement of the industrial engineers, who, ignoring deep-seated instinctive trends and attitudes in workmen, went ahead with stop watch and efficiency schemes to increase the productivity of industry. A knowledge of psychology and sociology might have saved them many disappointments and made possible more adequate and humane methods of accomplishing what they set out for. Even the applied psychologist in industry to-day is rather ignorant of the socio-psychological factors behind trade-unionism, such as fear of economic insecurity and the like.

To recapitulate the implication of all this: While we need the humanizing of knowledge of which James Harvey Robinson has so brilliantly spoken, it is particularly through the integration of attitudes and action among scientists and their near-kin, the technologists, that we may look for acceleration of social change. Likely enough some retrogression may result from a lack of perspective. A narrow conception of, a mere technical interest in, chemistry, for example, may conceivably result in a horrible use of chemicals in the destruction of the very civilization chemistry has had such a place in producing. Not only must the scientists realize the interrelations among their fields, but even more so must they see that unless an integration of natural and social science with ethics and living be made, no lasting progress will be possible.

When the scientists themselves begin to see the significance of these matters, they will be able to forge for the technicians, and through them for the masses, tools with which to pry the universe further to our own liking. One may have a pious hope for a future general dissemination of the scientific attitude in the masses, but the history of man's culture has given us little basis for belief that this wish may be materialized. There is actually more evidence that the general run of mankind always has been and always will continue to be controlled by socially concrete and technological frames of behavior laid down for them and carried on by prestige-bearing persons in the group. Therefore, the integration of the

[11] *Cf.* T. Veblen, "The Engineers and the Price System," 1922, for comment on this matter.

scientific attitudes among the scientists and technicians themselves is highly desirable, in fact inevitable, if the results of science are to replace, except helter-skelter, the schemas of the traditional medicine-man and magic worker. For the men in natural and social sciences must become "the authorities" who set the patterns of man's behavior. When the cooperation of scientist, technician and socio-economic executive is formed, we may hope to see the day of rational ethics and really humane living approaching. The present failure of science to be applied humanely for social welfare rather than for special privilege and economic power may in time prove a great barrier against its ultimate importance for the common run of all. Science is but a fraction of human culture and until it is so recognized it must remain essentially apart from serving as an integrative principle in the mutual development of personality and a sane social order. For the scientist, no matter how abstract and removed he is from the present life to-day, must not forget that ultimately science must pay its debt to the society which makes it all possible.

EDWARD LIVINGSTON YOUMANS, A NATIONAL TEACHER OF SCIENCE (1821-1887)[1]

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IN Europe some of the greatest investigators have carried on their work independently of the universities and other teaching institutions. Many names occur at once: Leibnitz, Descartes, Pasteur, Darwin, Galton. In the United States it seems that the greater scientists have usually been teachers. Agassiz, Asa Gray, Rowland, Newcomb, J. D. Dana, William James, all held teaching appointments. If this difference be a fact, the explanation of it may be difficult to discover. It can not lie in the leisure of the American university teacher, for as compared with the European conditions, such leisure does not exist. Our teachers have done scientific work of greater or lesser moment, if not in spite of their teaching, then certainly in addition to its heavy load.

As we have had investigators who were primarily and regularly teachers, so we have also had some great teachers who have maintained no connection with a school, or better perhaps, teachers whose school was the nation as a whole. In this class Emerson would be found. It is to this class that Youmans properly belongs. Although he was called Professor Youmans his only collegiate connection was a very temporary and rather irregular one with Antioch. And just as he was not a professor, so he was not a discoverer. As a scientific investigator he has to take a low rank; but as a teacher of the science discovered by others he achieved a high one. He taught a nation by his books, by lectures and by means of a well-known journal which he established and for many years directed, *The Popular Science Monthly.*

Edward Livingston Youmans was born near Albany, New York, in 1821. He was, therefore, about two years younger than James Russell Lowell and two years older than Matthew Arnold; and, although he visited old England and New England frequently and was in close touch with authors and publishing interests in the two continents, yet one can recall no reference to either Lowell or Arnold in his correspondence nor any indication that he ever saw either of them. Although he was a good writer and an excellent

[1] The biographical facts of this article are for the most part taken from the life of Youmans by John Fiske.

speaker, he was almost blind on the literary and artistic side. Science sufficed him for a life-interest, science and human nature, for he was the friendliest of men.

He came of English and Dutch stock, as beseems a man from central New York. His mother had been in early life a school teacher; his father was a farmer, wheelwright and wagon-maker. They were not wealthy, nor were they poorer than the average of their community in rural New York one hundred years ago. But money was scarce and wages were often paid in kind. It was in the days of homespun, hand-work, hard work and long hours.

Edward—his given name was Livingston after a revered pastor and the Edward was self-adopted later on—was an industrious and capable lad and made good use of the meager cultural opportunities of his environment. Because of his ability his pious grandmother, and his mother, too, wished him to become a minister. And as he travelled the unexpected line of development which he did follow through life he sometimes—and entirely seriously, of course—assured his rather Puritan parents that it was not necessary to be a clergyman to assist in the work of saving souls. In his mind the sharp distinction between sacred and secular affairs had faded and he regarded the spread of scientific teaching and the imparting of practical information as the most valuable and important work in the world.

It is apparently not difficult to see the reasons for this conviction or the steps by which it was attained. Labor-saving devices in the house, improved implements, better and more abundant fertilizers for the thin acres were immediate necessities. The boy's early life was spent in farm and mechanical labor. Educational opportunities were limited partly because of the environment and partly from lack of financial means. Although he read whatever he could get, the supply was limited; and yet it included "Don Quixote," some of the ancient classics in translation and, particularly, Comstock's "Natural Philosophy," a chemistry by the same author and Buffon's "Natural History." It may be that his mind had an inherited bent toward scientific thought and study. Certainly, the most impressive achievement of his boyhood was the construction of a centrifugal water-wheel which excited the interest of the neighborhood, because it actually revolved and especially as it moved—as such wheels do—in a direction opposite to that of the stream which propelled it.

Since he would not be a minister and since he would be an educated man, his parents wished him to become a lawyer. He seems to have favorably considered this goal; but before he was to enter upon the special studies of a profession he suffered from an affec-

tion of the eyes which with its alternate improvements and relapses lasted from his seventeenth to his thirtieth year. His trouble was so serious that it would have reduced a less indomitable personality from an aggressive worker to a charge upon his family. In a period of improvement he had begun teaching in a country school in order that he might help to defray the expense of a prospective college education. Renewed illness cut short his teaching career. His difficulties were aggravated by overstrain, probably on the theory that blindness is to be preferred to ignorance; by exposure and colds, which led to severe inflammation; and finally by the ignorant malpractice of a quack oculist, which completely extinguished the sight of one eye and permanently impaired that of the other.

In the hope of securing competent medical advice he went to New York City when he was about twenty years old. He did get aid and he found work and sympathetic friends, among them Horace Greeley and Walt Whitman. At times his vision improved so much that he was able to find his way unaided about the city; but the least exposure or nervous excitement would cause a relapse into total blindness that often lasted for weeks. By the age of thirty, as a portrait taken at that time shows, he had developed the characteristic facial expression of the blind, and his friends and sometimes he himself had given up hope that he would ever recover his sight to any useful degree; yet recover he did and that almost suddenly, as will presently be told.

Meanwhile he did not sit idly by. He found odd jobs around newspaper offices, writing advertisements and reviewing or making summaries of new scientific books. Much of the work could not be done unaided. Friends read to him when they could spare the time and also took his dictation. However, like Prescott, he invented a frame to hold his paper and guide his hand. Eventually his sister Eliza, who had scientific tastes like himself, came to him, and the two formed a lifelong partnership in work reminding one of Sir John Herschel and his sister Caroline. Eliza found a position as a teacher. On Saturdays she had access to a laboratory and carried on experiments in chemistry and studies in botany. Evenings she read to Edward, recounted the results of her studies and prepared his manuscript.

He was not lacking in projects. One was the preparation of a history of scientific discovery. With his sister he ransacked the libraries and the bookstores of the city for information. On one trip the two went into Appleton's, when Mr. W. H. Appleton, then head of the firm, seeing the situation, instead of selling them the book for which they asked, offered to lend it to them and also say

other book which they might want. In this way began a connection fortunate and profitable both for Youmans and for the firm in question. When the history of scientific progress was well under way, Youmans found himself anticipated. Another book on the same lines was published in New York. A second project was the preparation of an arithmetic more practical than those then in use. He planned to introduce concrete problems taken from practical affairs and from current science and to use in the problems the constants of the various sciences instead of the abstract and unreal problems and quantities with which school arithmetics were then filled. At once he began writing the book. Again he was anticipated, this time by Horace Mann, who, as co-author with Pliney E. Chase, in 1850 published a book called "Arithmetic Practically Applied." Of this book, which is never mentioned by the historians of education who make so much of Mann, a competent critic, Mr. J. M. Greenwood, says: "A revised edition ought to be in the hands of every teacher. It has never been properly appreciated, and few copies are in existence; even the publishers do not have a copy."[3] But before Youmans learned that his ideas on arithmetic had been anticipated he had succeeded in another direction.

At this time, that is, about 1850, and for years after in many cases, chemistry was taught in schools from a text-book only, without laboratory or demonstration. Even Harvard followed this plan until the fall of 1851, when chemical demonstrations by the instructors were introduced. Laboratory work by the students came still later. It occurred to Youmans that if by means of a chart and colored inks chemical combinations could be visually represented to students, clearer ideas would result. Doubtless his blindness was here an advantage in disguise, for in the long intervals of sightlessness he could not follow his sister's experimentation except as he visualized her descriptions of the processes. The student without a laboratory appeared to him very like a blind man. Accordingly, he devised diagrams and combined them into a complete chart showing the theory of chemical action as then understood. The chart was exhibited and called out much interest and favorable comment at a fair held in Castle Garden. It was then put on the market and had a wide sale. But its chief importance to Youmans was an indirect one, for it led him to the successful completion of his first book, "A Class-Book of Chemistry," published by Appleton's. The preparation of the text had been most carefully and, therefore, laboriously carried out. He speaks somewhere, although

[3] Report of the U. S. Commissioner of Education, 1897–98, vol. 1, p. 854; and also W. S. Monroe's "Development of Arithmetic as a School Subject," p. 118. Messrs. E. H. Butler & Co., Phila., were the publishers.

perhaps not in connection with this first book, of breaking up and rewriting a certain passage fourteen times. When he had several chapters ready he sent them to Appleton's for an opinion. The reply soon came as follows:

> These pages give promise of an excellent work on chemistry. The author evidently understands the science and possesses a clear, logical mind. His manner of presenting the various subjects is quite full, and his thoughts are practical and such as can not fail to make a striking impression on the youthful mind. The "atomic theory" and the subject of chemical combination are not more clearly handled in the works of either Silliman, father or son. More attention should be paid to punctuation.

With golden words of praise like these, including the comparison with the elder Silliman, the Nestor of American science, any young author might well have been content, and the stricture upon his punctuation must have seemed a slight matter. The book was finished and published in 1851. It was twice revised by the author and sold in his lifetime 100,000 copies or more. This was by a long way his most popular book.

Fortune smiled, the future looked bright, and indeed it was so. Success relieved his mind of its care, his general health improved and with this improvement his sight in one eye returned so that he could read easily and could, of course, go about and was able to recognize his friends. His face no longer gave the impression of blindness. "When the chemistry was finished in the autumn of 1851, its author had been for eleven years under the care of an oculist." Now and for the rest of his life he could dispense with such service, but he was always very nearsighted. It was perhaps for that reason that he cared nothing for scenery—he did not enjoy the Highlands of Scotland nor the Alps, and thought art criticism a humbug.

The second phase of Youmans's life now opened, his career as a lecturer on science. He was thirty years of age. His speech was fluent; and of its raciness we will soon see some examples. He had read and listened to a great deal of scientific literature, had thought much in his hours of darkness upon the deepest as well as the most immediate scientific problems, had heard great scientific lecturers, including Agassiz, and had been prepared for all this in boyhood and youth by a course of observation and investigation in a laboratory not to be utterly despised—the old-fashioned farm. Going as far west as Wisconsin—and Wisconsin was the Far West then—and covering chiefly the Old Northwest, New York and Pennsylvania, he pursued his new vocation for seventeen years (1851–1868). This was the period when the lyceum platform was still popular, and when the renaissance of science under the influence of the theory of evolution had all the interest of a great discovery

for the young collegians and high school students in regions which public education was rapidly preparing for the reception of the new ideas.

In the middle of this period of lecturing when he was making a place for himself both among the American people and in the publishing house with which his interests became more and more identified, Youmans formed a friendship with Herbert Spencer. He had seen a review of Spencer's "Principles of Psychology" in the year 1856 and had sent to London for the book. Both he and his sister were interested by the author's theory of mental development, read the same writer's "Social Statics" and then began to search the British reviews of the day for his unsigned articles. This was several years before the "Origin of Species"; and it is another bit of evidence that the thought of evolution was a stimulating one in many minds at the middle of the last century, including those of these self-taught scientists of New York.

The first letter (1860) of Youmans to Spencer is so informing and characteristic that we quote:

> *Dear Sir:* My friend, Samuel Johnson, Unitarian clergyman, of Salem, Mass., yesterday called my attention to a letter and circular from yourself, proposing a reissue of your writings. I was not only greatly pleased with the idea, but the circumstance was especially fortunate for me, as it gave me a clue to your whereabouts, which I had for some time sought. I was on the point of writing to Dr. Chapman [editor of the *Westminster Review*, for which Spencer had written] for your address. My purpose was this: I meditate the compilation of a volume designed to present the increasing claims of science upon teachers and the directors of education, to contain the addresses of Faraday, Whewell, Tyndall, Paget and Daubeny before the Royal Institution, on the popular claims of their respective branches of science, together with the address of Agassiz on kindred points, and your own article in the *North British* (I think), which was omitted from the edition of your essays. There is still another article, the opening one in the *Westminster* for last July—"What knowledge is of most worth"—which I wish to include, and my solicitation was to find its authorship. I concluded before I had read a page of it that you wrote it; the full perusal strengthened my conviction; yet, of course, as I may be mistaken, I wish to find out about it. I might have applied to the editor of the *Westminster*, but Scott, the republisher, tells me the conductors are often shy and delicate about giving this kind of information. I should therefore be glad of an assurance from yourself; and if I happen to have been mistaken, would you not probably be able without trouble to inform me who the author is?
>
> Respecting the plan of your publication, I had no opportunity to learn anything, as I had not time to read the circular. But whatever you propose in the matter I fully accept, and will most gladly do anything in my power to forward the enterprise. I have published several elementary books by which I have been somewhat mixed up with book men and the book business, and this circumstance may afford me some opportunity to aid the object. I am more or less connected with the lyceum system throughout the country, and, dealing with scientific topics, I fall in with the class of men who would take most interest in your current thought. . . .

The prospective book to which this letter refers did not become an actual one until 1867, when he edited and the Appletons published "The Culture demanded by Modern Life," a collection of addresses and arguments by various authors on the claims of scientific education. Spencer's reply indicated his wish to retain control over his essays on education, as follows:

> . . . Referring to your question concerning the article, "What knowledge is of most worth?" you are right in ascribing it to me. I should, however, regret to see it and the one from the *North British* included in the volume you contemplate, because I am myself hoping, in the course of a year, to republish these articles, along with an equal bulk of matter on the same topic, in the shape of a volume on education.

Spencer's "Education" was shortly thereafter offered to Ticknor and Fields, Boston. As they refused it, Youmans persuaded the Appletons to take it, and also to undertake the publication of Spencer's other works.

More and more he became not only the "interpreter of science for the people" and the "apostle of evolution," as John Fiske has happily named him, but, in particular, the leader of the vanguard of the Spencerian philosophy in America. Indeed, he became far too much a mere disciple. In advertising Spencer's ideas and writings and looking after his business interests he spent as much thought on that author's affairs as some successful men spend on their own. One illustration of the length to which he would go is found in a note from Spencer, from which I copy:

> I see in the account [from Appletons, his American publisher] the item, "seven copies of the Essays sold to Professor Youmans." Surely you have not been throwing away your money on my books to give away! If there are any presentation copies which you think it well to give, pray always order the Appletons to send them and debit me with them.

When Spencer, before his writings had become popular and profitable, had sunk five or six thousand dollars in the publication of his philosophy, Youmans persuaded American admirers of the English thinker to make up a purse of seven thousand dollars, and by representing that it was not intended as a reward or a mere gift but as an investment to insure the continuance of important work, he presented the matter and the purse so skilfully and delicately to Spencer that a refusal would have seemed ungracious. In a letter of about this time, Christmas, 1864, Youmans wrote:

> Henry Carey called in to blow up the Appletons for publishing Spencer's British free-trade doctrines. Spencer was an upstart; his system would soon die, like Comte's and Mill's. Said W. H. Appleton, "I can tell you one thing—Spencer won't die as long as Youmans lives."

Youmans was married in 1861 to Mrs. Lee, the widow of a New York lawyer and jurist. The following year they visited England.

One of his first objects was to see Herbert Spencer. They found him in Scotland, and he brought them back to London to meet Huxley and other scientific workers. On this first of half a dozen visits to Europe he also spent some time in studying English education, particularly the Borough Road training school for teachers, and attended the meeting at Cambridge of the British Association for the Advancement of Science.

To arrange for the overseas publication of his book "The Culture demanded by Modern Life," already mentioned, he went to England a third time in 1868. The volume contains papers by Tyndall, Huxley, Liebig and others, essays which he exhumed from the transactions of learned societies and the files of periodicals and to which he thus gave a new and wider currency. There are also two papers by Youmans himself: "On mental discipline in education" and "On the scientific study of human nature." The second of these articles was prepared in England and was delivered as a lecture before the College of Preceptors. It presented the view that human nature is a subject for scientific study and stressed the importance of physiology in that study. Its point of view would still be considered a modern but no longer an advanced one. In a letter to his sister Youmans gives an interesting account of the delivery of this address, from which one may quote a few sentences:

The lecture on the "Scientific study of human nature" came off as per appointment at the room in Queen's Square, where you heard Hodgson. . . . Kitty [his wife] went with me. Just before I began, in came Tyndall. I thought I saw through that dodge in a moment. Spencer is out of town . . . and as he was evidently solicitous about the result he got Tyndall to go. Whichever way it be, it was fortunate, and I am certainly much obliged to him for his consideration, for the meat was too strong for the babes. They were restless, and as I said thing after thing, a dozen pens sprang convulsively to paper, to note them down and blow them up. There was the closest attention, and at all events I had them well in hand. At the close there was cordial applause—as usual, I suppose. A gentleman then arose, and said he was attracted to the meeting by the announcement of my name, having read a very remarkable argument in the shape of an introduction to a work on chemistry lent him by his friend, Dr. Farr (to whom I had given a copy), and he said, "I was, therefore, less taken by surprise at the paper we have just heard than most of you have evidently been." After a very pleasant and excellent address, in which he said Locke had laid down the true view of the basis of education two centuries since, which, if followed out, would have produced the most beneficent results, he sat down and Tyndall arose. He made an exceedingly neat and happy address into the very notch of the case. He put the plaster on large and thick and close, as he best of all men knows how to do and the consequence was that all subsequent remarks were but adding lesser patches. . . . Tyndall escaped before I could speak to him, but I dropped a note to him next morning, thanking him for his kind consideration in coming, for his too partial remarks, and for his shielding me from the little hailstorm which I should have undoubtedly experienced otherwise. He replied, saying: "I quite expected the little

hailstorm and was astonished to find what you said (for the view was very strong for such a place) so heartily appreciated. Believe me, when I say from my very heart, the paper surprised me as much as it delighted me."

It turned out that Spencer had not sent Tyndall, but that, as was amusingly common with the philosopher, he did not arrive because he was under a wrong impression in regard to the time.

The "Culture," in which this address was inserted, had a wide sale and has not by any means been forgotten even now, as one may see, for example, by looking into the third volume of Graves's "A History of Education."

The two most important achievements of his life were, doubtless, the founding of the "International Scientific Series" and of the *Popular Science Monthly.* The "Series" came first, and Youmans on his fiftieth birthday found himself on the mid-Atlantic on his way to engage English, French and German contributors to the venture. Among the foreign scientists whom he introduced to American readers through this series of books were Bain, Buckle, Lecky, Tyndall, Helmholtz and Darwin. During its editor's and projector's lifetime more than fifty volumes were issued and the series had proved a decided success. The arrangement was for the simultaneous publication in America and in foreign countries of authoritative scientific books for the people. Youmans, a man of the people, by his service on the popular lecture platform speaking on scientific subjects, was well qualified to estimate the interests and the understanding of the public. And, on the other hand, the confidence of Spencer, Huxley, Tyndall, Lubbock and, from this time on, of Darwin also, in his acumen and his business honor, went far to smooth the way with the scientists whose cooperation was essential. Youmans went on the theory that popular scientific books should be written by the masters. The "Series" was opened by Tyndall's "Forms of Water" and one of the most successful volumes was Spencer's "The Study of Sociology." An incidental although not unforeseen result of the publication arrangements was that the authors could enjoy the advantages and pecuniary rewards which were only long after secured to authors in general by international copyright.

Hardly was the "International Scientific Series" well launched when the *Popular Science Monthly,* full-rigged, was also set afloat; or perhaps we should adopt the figure which Youmans used and say that it had a very short period of gestation. If so, the *Popular Science Monthly* was born in May, 1872. Although it has changed its publishers, its editor several times and its name (to THE SCIENTIFIC MONTHLY), it has always been one of our leading scientific periodicals.

The idea of a magazine had been under consideration by You-

mans and the Appletons for several years, and they had indeed made one not very successful venture with a weekly; but when Herbert Spencer in March of 1872 sent Youmans the first instalment of "The study of sociology," the ardent recipient wrote: ". . . I decided upon our course two minutes after getting it. I determined to have a monthly at once, and in time to open with this article. It was vital that these articles be not exposed to the temptation to reprint them in pamphlets." And, although not at all a miracle-man in any sense of the word, when Youmans decided to have anything he generally had it. In this way *The Popular Science Monthly,* a magazine of 128 pages, with an original article by Spencer, a translation from Quatrefages by Eliza Youmans, a liberal use of selections, a few editorial pages and some book reviews, was started.

Clippings from English magazines were for a long time used extensively in the make-up of the *Monthly.* And although the scissors can hardly be regarded as a proper editorial instrument, yet they were frequently used; and very carelessly at times, for Youmans in one case admitted that he had inadvertently printed (Vol. VI) a "medical humbug" article only because he had not read it through.

The character of the *Monthly* was decidedly popular rather than scientific, and scientists complained of this, notably Simon Newcomb, although he remarked that the journal was improving in this respect. We must note that it was in the 70's when Newcomb deplored the scarcity of American scientific research and especially "our beggarly and humiliating showing in the exact sciences." Youmans replied that his work was necessary, for the scientists themselves had rejected popularization and had left it to half-instructed men. He was on safer ground when he added that the *Monthly* was founded to educate the non-scientific public in scientific matters.

The conception of his task also explains the nature of his editorial writings. He dealt with many subjects, current scientific progress and events, the visits of foreign scientists of note, the controversy between science and theology, and, more than any other one topic, scientific education. Criticism of the literary content of education and especially of the stress placed upon the "dead languages" is abundant in his columns. He was hardly fair, although the work which he tried to do needed doing. Perhaps hard blows were required to open any door at all by which science might enter into the more conservative schools. Gentle as he was by nature, when he was writing on this subject he seems to have preferred to borrow the iron sledge-hammer of Spencer rather than the ringing

silver mallet of another friend. It was Tyndall, not Spencer, who had written:

> Is there no mind in England large enough to see the value of both [science and philology], and to secure for each of them fair play? Let us not make this a fight of partisans—let the gleaned wealth of antiquity be showered into the open breast; but while we "unsphere the spirit of Plato" and listen with delight to the lordly music of the past, let us honour by adequate recognition the genius of our own time.[3]

Youmans spent his life, if we may use a quaint old English phrase, in "the diffusion of scientific knowledge." As a survey of his editorials in the *Monthly* and of his other publications has shown, he was interested not only in science but especially in the teaching of science. Great scientists, as well as those less great, are sometimes tempted to look askance at popularization, to view teaching, this dealing in the small change of scientific currency, as piddling business; as if, without showing their competency with small sums, children were to be entrusted with large. Teachers, on the other hand, have their own views of the man of science. They may regard him as narrow and remote, somewhat inarticulate even in his own proper field and socially a feckless person. Rarely would either of these recriminatory views be wholly true, yet the tendencies are perhaps common enough to be recognized.

The scientist may become so engrossed in his specialty that he will do little or nothing toward the spread of his discoveries. Sometimes he fears controversy and its time-consuming entanglements. So did Newton. His views called out such opposition that he "was tempted to publish nothing." "I was so persecuted," he wrote to Leibnitz, "with discussions arising from the publication of my theory of light that I blamed my own imprudence for parting with so substantial a blessing as my quiet to run after a shadow."[4] But while fame may sometimes be merely a shadow the results of publication can be shown to be thoroughly substantial.

The value which accrues to science itself from its wide dissemination is great. The wider the extension of a new doctrine the greater is the stimulation of latent scientific talent. The spread of a new idea attracts new workers into the scientific net. While teaching, whether by voice or pen, through illustration, experiment or argument, does encroach upon the expositor's time—time which might be devoted to further investigation—it is not time lost if it calls out new recruits.

As Youmans no doubt perceived, scientific theories gain greatly from the effort to clarify their thought and to expand it to the point where youth, and perhaps dullness, can understand it. The

[3] Essay by Tyndall in "The Culture demanded by Modern Life."

[4] David Brewster's "Life," p. 63.

meaning of scientific discovery becomes clearer by its exposition; and original ideas may be lost for a long time because they are not presented so clearly and voluminously that they can make an adequate impression upon a large public. The history of science furnishes many examples, Mendel for one. This point was well understood by one of the greatest of scientists and of scientific expositors, Charles Darwin. In the autobiography which is included in the great "Life and Letters" by his son (pp. 69–70), Darwin wrote:

> . . . our joint productions [A. R. Wallace's and his own in the *Journal* of the Linnean Society in 1858] excited very little attention, and the only published notice of them which I can remember was by Professor Haughton of Dublin, whose verdict was that all that was new in them was false, and what was true was old. This shows how necessary it is that any new views should be explained at considerable length in order to arouse public attention.

Darwin's whole account of the preparation of the "Origin of Species" and his other writings, of their publication and their effects is of interest and practical importance to scientific writers.

Teaching and popular presentation, however, require talents of their own and somewhat different from those required for original work. The same man may excel in both directions as did Darwin. Yet, as originators are rare, their time is correspondingly valuable to society. Youmans did good service by stimulating the production of manuscripts, by editing them and by developing a market for new ideas. His keen, trained intelligence and his sustained interest in scientific research and discovery fitted him on the scientific side for this task.

Influence is hard to trace and even more difficult to evaluate; but there is considerable evidence that as a writer on chemistry, as a lecturer on science, as an editor and as the founder of an important journal he was widely influential upon the growth and spread of science in America. "I am not among the fortunate mortals," he wrote in 1883, "who do work that is to survive. Yet *The Popular Science Monthly* is bound up in all the American public libraries, and it will hold its place there by sheer force of its bulk—it will hold over at least into the next century; and I am contented that it contains evidence that I knew a good thing when I saw it." With this modest opinion we can not, except on the score of its modesty, disagree.

SOME "SOCIAL NUISANCES"

By W. W. KEEN, M.D.

EMERITUS PROFESSOR OF SURGERY, JEFFERSON MEDICAL COLLEGE, PHILA.

I HAVE read with great satisfaction and keen enjoyment Professor Knight Dunlap's paper in THE SCIENTIFIC MONTHLY for September, 1923. With almost everything he says I am in hearty accord. With two—the Antivivisectionists and Prohibition—I am in disagreement on some points.

I—ANTIVIVISECTION

(A) That experimental research sometimes does inflict pain on animals is true. That some wanton and reckless experimenters disregard such pain is also true. The latter have lost caste in the profession and, in any case, are few in number and becoming constantly fewer. "Inflicting pain" is not synonymous with "cruelty." For instance, to ride a horse to death to procure medical or surgical help in an emergency, or to sacrifice lives and cause even hundreds of men to suffer mutilation in a "feint" attack to mislead the enemy from the real attack is as old as war and is not "cruelty." The 17 hogs which yielded up the secret how to abate hog cholera and almost wholly to conquer it, did suffer pain undoubtedly (though pain diminishes from man downwards in the scale of living beings very rapidly, as judged by our only standard—the exhibition of suffering), but was not this infliction of pain justified a thousandfold by the saving of the lives and suffering of millions of other hogs?

So, too, by infecting 25 monkeys and 100 guinea pigs with the poison of cerebro-spinal meningitis, Flexner was able to reduce the mortality of that dread disease from 75 per cent., and sometimes far more, to 25 per cent., and sometimes far less. Does not common sense justify this vicarious suffering? Should it not be praised and fostered if we can thus discover a trenchant weapon against scarlet fever, measles, cancer, etc., instead of being condemned or still worse prohibited?

When the Germans, in 1915, at Ypres, in spite of their thrice repeated solemn promise at The Hague and in the Treaty *not* to use poison gas, did use it and slew some thousands of brave Canadians, when its internal effects and the means for protecting our soldiers were wholly unknown, what was the proper course to pursue in order to protect our soldiers:

(a) To experiment upon dogs, which undoubtedly suffered great pain, and quickly find the means of protection, or

(b) To await the experiments the Germans inflicted on our soldiers and slowly and imperfectly learn by their sufferings and death how to combat this dreadful new weapon?

I am almost ashamed to ask this question, for common sense and humanity combine to commend the first and quickest.

(B) Would Professor Dunlap be satisfied if, at the Massachusetts Institute of Technology, no engineer was allowed to see an automobile engine in motion but only as a motionless dead machine? I trow not.

As I know by my own personal experience and as a teacher of surgery for over 40 years, to see only a dead, motionless heart gives only a faint idea of its wonderful action. How it thrills me to see it actually in active motion! And then to destroy the little group of cells in the furrow between the auricles and the ventricles, and to see how the regular sequence of the normal contraction and relaxation of the auricles and ventricles changes to unregulated action, to wild, physiological chaos! Never can a mere description or a mere inspection of this wonderful human "motor," as a dead and motionless machine, give a *real* idea of its action and its value.

The removal of the pancreas in a few dogs—which all died from diabetes—was the key to the discovery of insulin. Who would dare to stay the hand of the experimenter who, by such means, led to the discovery of insulin?

Professor Dunlap objects to "mere demonstrations" of the workings of the heart, lungs, intestines, uterus, etc. To my mind they are essential and unavoidable means for giving human "engineers"—the physicians, surgeons and obstetricians, to whom we all commit our own lives and the lives of our dearest—a lively and living idea how these organs perform their functions.

Some of these demonstrations can be carried out by killing the animal and at once removing the heart or inspecting it and other viscera, and if so, it would, of course, to some extent answer the purpose.

II—Prohibition

The able editor of the *Atlantic Monthly* for October (p. 573) commends an article on this subject as an effort to "refocus thought upon what has become a condition and not a theory." Let us look, therefore, upon some of the existing conditions.

In many, if not in most (or all?) of our treaties with the Indians, the sale of liquor is prohibited. That this provision has been shamefully violated is not the question. The *motive* for such a prohibition and its *effect* when and where *made* effective, is the

question. I venture to say that in no place in which this provision was made effective by the Indian agent of the government was the effect anything but beneficent.

In introducing civilization among the African backward nations, the sale of alcoholics and of arms and ammunition has in general been prohibited. Why? Evidently, because as in the case of the Indians, its harmfulness—great harmfulness—was acknowledged. Again, wherever this prohibition has been effective, the result has been to the good.

Are not these two instances convincing as to the prevailing opinion of civilized governments and peoples that the indiscriminate, unrestricted use of alchohol is noxious? Did anybody ever raise the question of the restriction of "personal liberty" in such cases? If any one had done so, would not common sense have brushed it aside as irrelevant and even arrant nonsense?

Is "personal liberty" different in civilized and uncivilized nations?

In the United States the 18th amendment was passed, as declared by the Supreme Court, in the perfectly legal way prescribed for amendments of the Constitution. It was debated in private and public, in the public press *ad nauseam,* in legislatures, in both Houses of Congress, and recommended by both of these Houses, and has been adopted, if I remember rightly, by 46 states out of our 48. It is the "supreme law of the land" as declared by the Constitution itself. It has been affirmed that even before its adoption over one half of the United States was already "dry."

Salus Populi Suprema Lex

The blessings of prohibition were eminently shown when it was solely a war measure, not only in diminishing the evil of drunkenness, but also the almost worse evil of venereal diseases.

Its blessings, to-day, in spite of its defective enforcement, I showed in my address in Paris as President of the International Congress of Surgery in 1920 (*Annals of Surgery,* September, 1920).

It has been a boon to the mothers and children of the land. "Tell us how to vote dry" was the pathetic cry of the working women of Philadelphia to speakers at many public meetings. Their husbands, instead of squandering their money on drink, were spending it in better clothing, rational amusement and loving care of their wives and children. Their savings banks accounts were greatly increased all over the land.

The testimony of large employers of labor (*Manufacturers' Record of Baltimore*) was overwhelmingly in favor of prohibition. Their turn-over of labor was far less; their men were on hand on

Monday morning instead of sleeping off the sprees of Saturday and Sunday. Accidents caused by minds befuddled with drink were far less frequent, saving money to the employers and life and limb to the workers.

Many of our railroads prohibit any drinking by their employes while on duty. Why? For the same reasons as above given. It pays the railroads in actual cash to stop drinking, as it does the employers in manufacturing and commercial establishments.

Professor Léon Bernard, of the medical faculty of the University of Paris, in his report on what he had seen in a widely extended visit to this country testified to the same good effects of prohibition (Bulletin of the Paris Academy of Medicine).

"The effect of alcohol on longevity" is a study based on nearly 6,000,000 persons whose lives were insured in the United States, Canada and Great Britain and showed that in direct proportion to the greater use of alcohol the death rate increased from 100 per cent., for non-users, up to 182 per cent.; the average of all grades of drinkers being 132 per cent.

Said an intelligent Englishman to me lately: "In England we shall be driven to prohibition for economic reasons. A non-drinking nation for the reasons just given will always be able in the long run to undersell a drinking nation in the markets of the world."

That liquor can be, and is, obtained so freely is largely to be laid on the doorsteps of Congress. They refused to place officials under the Civil Service Board and made the appointments—to their shame—political appointments. This effect is well shown by Mr. Haywood in the *Atlantic Monthly* article already quoted—the very men appointed to enforce the 18th amendment in many cases are false to their trust and abet its violation. "What are we going to *do* about it?" he asks. Give the country time, and the violators of the law will find out. The great mass of the people, the working men especially, are in favor of prohibition and Congress and the officers of the law will find out and trim their sails accordingly. Public opinion will compel observance of the "supreme law of the land."

THE BIOTIC FACTOR IN FORESTRY

By EDWARD N. MUNNS
FOREST SERVICE, WASHINGTON, D. C.

ALL too often the biotic factor in forestry is overlooked. We take note of the soil and its moisture, of evaporation and of wind, of cover conditions, altitude and methods of logging, and ascribe to one or the other the reasons for the presence or absence of reproduction. All too often we look for the difficult thing, sometimes overlooking because it is too obvious the occurrence of a factor of perhaps even more importance than methods of lumbering.

Most of our timbered areas, where man has not upset the natural balance, are well peopled with all sorts of animals from the lowest to among the highest. Not all this population is harmful to man and some is of decided benefit, and foresters would be the last to decry any denizen of the forest where the damage has been slight. While the rancher may be cursing the deer that nibble his fruit trees and spoil his vegetables, the forester may be bemoaning the diminishing number of deer in his domain. On the other hand, the forester joins the rest of the human race in attempting to exterminate the many rats and mice, not alone because of the food they spoil or the clothes they ruin, but also because they are agents which are helping to bring about the inevitable timber shortage.

Of late, we have come to realize that the biotic factor, especially as applied to the smaller rodents, is an important one. Mr. and Mrs. Rodent's fear of a hard winter leads them to store the Douglas fir seed in the heavy layer of duff and now foresters are using this characteristic as a recognized practice in forest management of the Pacific Northwest. Because the summers are long and hot and dry in parts of California, the pack rat finds his best drinks come from the inner bark of the pines, so he helps himself to the nearest young tree and, if the tree lives after a hard summer, it may furnish feed or drinks for other generations of pack rats. In the spruce country, because the tender spruce buds are rich in carbohydrates, young trees that show above the snow level are mowed down, so to speak, by the snowshoe rabbit, who esteems the spruce buds a rare delicacy. Even the forlorn cow or the wandering sheep will not starve before eating the young pine tree, and many acres of cut-over land in the southwest are devoid of young trees because of the good feed thus furnished.

After six years of excessive sheep grazing this young western yellow pine is all but a total loss. Overgrazing on many ranges has killed out the valuable forage plants and left the unpalatable feed to take complete possession. Pine trees are better than poor browse.

But we must not be too severe, for there are times when our rodent neighbors are most valuable to us.

Occasionally man desires to gather considerable quantities oi seed of these forest trees for his forestation work. To pick up the seed one at a time would require the patience of Job, so man often "collects the rent" from his free tenants by breaking into the apartments and carrying off all the edibles the pantry affords, if he can. Particularly in the west, the little pine squirrel is abundant and has the habit of making certain of food for a hard winter by storing the seed and cones of the forest trees. As high as 40 bushels of western white pine cones have been found in a single squirrel cache in Idaho! Spruce seeds are stored in little pits or depressions holding from only two to three cones to as high as sixty, and usually at the base of a tree, stump or log. Douglas fir cones are often found in a hollow strip or in a brush pile. White pine cones are commonly under large logs or between two parallel logs lying close together and in one instance, under water. Very rarely, indeed, are two kinds of cones mixed in the same cache. One thing about these caches that make them important is that the squirrel, unlike his forester friend, can tell the difference between good and bad

A SQUIRREL CACHE OF WHITE FIR CONES

This cache yielded about five bushels of cones which were piled up in a small depression near an overhanging bank.

seed, and in cutting the cones from the trees always gets the largest cones and those with the plumpest seed. With a heavy ladén seed tree to work on, a single squirrel will take every good cone, cutting them off the branch at the exceedingly high rate of one a second.

This little game of "he hide, you find" can be a most interesting one, as many of the seed collectors can testify, for it is one requiring mental alertness, not only to find what the squirrel has salted away, but to keep it after you have found it. On one seed-collcting job the cone pickers were ahead of the transportation system and had left several sacks of seed lying along the roadside. As the pickers are paid on a collection basis, they had a personal interest in those sacks of cones, but so had the squirrels. Two Frenchmen, the best in the camp, quit, and one told why: "Zee little teef, heem; I swipe me heem one sack, and heem swipe me two sacks."

Then, too, in the early spring one can go through the forest or brush field and find little groups of seedlings from 2 or 3 to as high as 150 in a single cluster just poking their heads through the ground. These are the little rodent caches planted perhaps by some chipmunk who may have departed this life during the winter when he failed to find his storehouse, or he may have not needed this particular little cache and so failed to return. Even in older stands we often see two or three trees and sometimes more in a group which look like sprouts around a single old root, but which are quite apt to be the result of one of these little clusters. In one brush field examined this last spring, 60 per cent. of the seedling western yellow and sugar pines found could be traced to rodent activity, and most of these were at considerable distance from the nearest living trees. On another area, larger than the first one, 37 per cent. of the seedling trees on a sample tenth of an acre were the result of rodent caches, and it is safe to say that these and similar areas have even a greater percentage planted by the rodents, though we can not yet accept the hypothesis that all our forests owe their origin to friendly chipmunks or squirrels.

The harmful work of the animals does not stop with the seeding operation; it continues into the small seedling stage. Birds, of course, like the tender tips of the seedlings as they are pushed out of the ground, and perhaps it is as much a delicacy to them as asparagus is to us. Mice, too, are not entirely unappreciative of this form of vegetation, though perhaps they do not care so much for the trees at this time because usually there is other tender growth available, and often, too, at this time the mice and other relatives are still hibernating.

As the seedling gets up a few inches and begins to make a noticeable growth, he calls to his attention the rabbits and some of the

On many areas of the West, the presence of the chipmunk has been responsible for the lack of success in seed sowing operations where forestation has been attempted without planting. The chipmunk hunts up every loose seed that is overlooked by the other rodents. At times he is a beneficial forest resident for he often plants the seeds and forgets where he put them.

other relatives of the mice. Tender buds, especially in seasons when everything else is dry and hard, have considerable water and nothing suits some of these folk better than a drink of pine juice *a-la-bud,* "cool and refreshing." In the winter when food is hard to get and the seedling's head sticks above the snow cover, the fresh tender green of the conifer can not be mistaken, and another year's growth is gone, or the bark, both succulent and nourishing, may be transformed into hops, and the rabbit, rat or whatnot goes off to find another one.

In many places the forester would like to establish a tree cover, and the only way open to him is to plant small trees, for merely putting seeds out is a delightful way of feeding the poor. But although the same animals that like the seeds may not take the tender nursery tree, others will, and many a forester has cursed long and bitterly upon reexamining a plantation to find that every tree had been taken by parties unknown, and that even the small plant stakes marking the trees have been removed wholesale and utilized in the making of pack rat nests. Burrowing creatures like the digger squirrel have buried the young trees with the dirt excavated from their burrows, gophers have found the roots to their liking, and moles even have drawn imprecations down upon themselves because they enjoy traversing the fresh dirt where the trees were planted, leaving the roots of the tree suspended in air.

Eventually under natural conditions the forest somehow or other gets established and grows, but man in his desire to utilize everything brings in a few thousand sheep and cattle more than he should. After eating all the more palatable feed and exterminating it, the livestock with one accord turn to the young forest for the next course and soon eliminate the possibility there is to make a forest again of the area. After making his peace with the sheep and cattle men, the forester heaves a sigh of relief, but while his back is turned the porcupine has climbed into the young trees in the polewood stage, and, many feet from the ground, proceeds to strip off the bark, causing the trees to take upon themselves all manner of queer shapes, if they do not die from the repeated attacks. Even the mature trees suffer from the depredations of the porcupines, and the prevalence of "spike-top" trees throughout the southwest is a monument to the porcupines.

There is, then, a constant strain upon the forester, and as he reads in his SCIENTIFIC MONTHLY about the many queer and powerful animals his primitive fathers had to contend with, he is thankful that they are not creatures of the present day that he would have to contend with. He yawns and goes to bed with the assurance that some fearful and wonderful monster will not start on a rampage and proceed to devastate whole acres of forest, pulling it up by the roots or pushing it over as it walks playfully through the forest. But even before he drops to sleep he realizes with a start that such a creature does exist. Woe indeed was that day when man developed his timber-harvesting machinery, that Frankenstein animal which so often spreads destruction and scatters fire where'er it treads, the "donkey" engine.

The biotic factor is truly an important one!

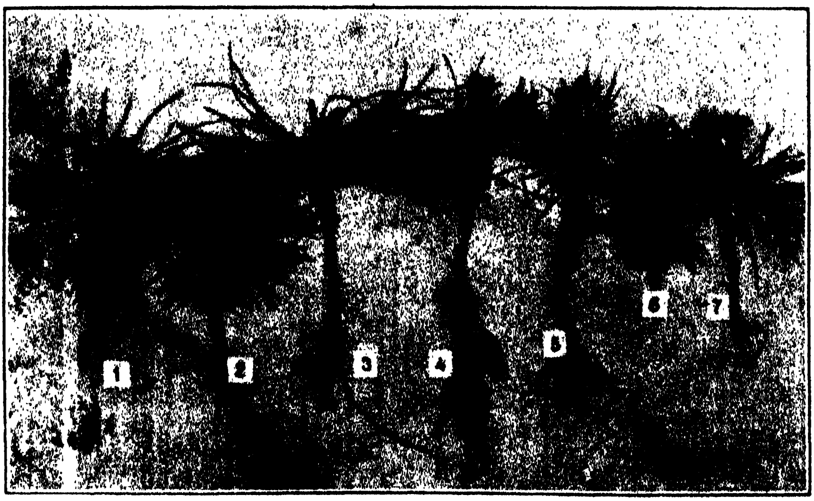
Nature, because she has so many children to feed, must provide for them with a lavish hand, and, because she must provide both for food and for the perpetuation of the species, her plant life must furnish much more seed than would otherwise be required to maintain it. In the forest she is perhaps just as generous as in the field or in the prairie, for the forest produces many thousand seeds per acre. Bates, in Colorado, found that a stand of spruce produced in one year over 41 pounds of seed or a total of 2,757,638 viable seeds, while a stand of Douglas fir produced per acre 11 pounds of seed or nearly 330,000 viable seeds. Yes, Nature sows with a lavish hand.

From the many thousand seeds produced per acre in every forest stand at intervals up to ten years, only two or three hundred trees per acre result and live to be a century or two old. Assuming, then, that in the virgin forest only 200 seeds are needed every two

centuries to take the place of the old stand, nature's lavishness is all too apparent. When man enters the stand as nature has produced it, conditions are changed markedly, for in place of waiting the two centuries to harvest a crop, he harvests his forest crop at around 50 years, and needs therefore four times as many seeds as did nature. In fact, he needs more as he raises, to be taken when 50 years old, perhaps three trees where one stood heretofore. He goes still farther, for he makes his ground produce all it can up to that period: at 15 years by thinning he takes out a crop of Christmas trees; at 25 years he takes out fence posts; he removes pulpwood at 35; he cuts poles at 40 years. Man's needs, therefore, can not be satisfied without a stand at the beginning of the new forest of between one and three thousand trees per acre, or about 8,000 trees every two centuries.

All this upset to nature's balance is reflected in the forester's actions. He can not now leave simply two or three seed trees per acre where seed trees are needed, he must leave three times as many, for the squirrels will take the pine cones before they begin to open, the seed that is left to be disseminated is eagerly awaited by the foragers who do not get off the ground, and if any seed escapes, it is because the rodents in that locality failed to smell or see it. So it is, unconsciously perhaps, that the forester leaves trees that he might otherwise have taken if some of his rodent enemies were out of the way.

Needing only about 2,000 good seeds per acre every 50 years



Trees from a plantation of Jeffrey pine in southern California. Plants 2 and 6 from a pack rat nest; roots on 1, 3, 7, cut off by gophers; roots on 5 taken by digger squirrels; roots on left of 4 killed by exposure to air in a mole tunnel.

there should be seed enough for both man and the smaller rodents and birds that formerly got it all, but man, unfortunately, wants his seed at a definite time and if anything interferes with their abundant and widespread sowing, that thing immediately becomes a factor detrimental to man's welfare and must be put aside. Unfortunately, man and other animal life do not speak the same language and, unlike other landlords, he can not give notice on the tenants and boarders of his apartment house to vacate on the first of May.

However, man must do something, and, as usual, he does the wrong thing. As a matter of policy he should require only the undesirable tenants to get out—the mice, the rats, the chipmunks, the squirrels and all their kith and kin—but instead, what does he do? First, he invites the lumberjack in and he makes no protest to the "man with the ax" when he destroys all the many enemies of the smaller rodents that he comes across in the day's work. A snake is a snake whether it be rattler or garter; a coyote may have rabies, besides he keeps the man awake nights with his music; a wild cat may attack him at any moment, a skunk is anathema on general principles; a fox has a good pelt; hawks and owls kill chickens; and so on. To the lumberjack a tree is to be cut, an animal is to be killed—values, size, location, quantity—all are alike to him, and the forester too often considers only trees and overlooks the biotic factor.

Second, the forester encourages the trapper and "points with pride" to his annual report in which 30 per cent. more pelts were taken this year over last, regardless of the fact that many of those pelts belonged to his friends, many of whom he should mourn.

Third, the forester tries to make the forest "sanitary" by putting into effect sanitation measures which will result in a "clean" stand at the next cut. Old logs, which harbor small rodents, are burned, but many of these old logs also harbor the rodent's enemies. Hollow trees and rotten ones which might infect the new forest with the most unspeakable (except by pathologists) fungi are destroyed, though the owl living there never caught the disease. Snags and old dead trees are cut lest they be struck by lightning or hold a fire for a long time, while the poor woodpecker who has done nothing but help to keep the destructive bark beetle in check has nothing left to drum upon but the tin roof on the ranger's garage.

Fourth, the forester encourages, aids and abets the tired business man, the city man, the "recreationist" of whom we have heard much of late, to come to our forests and renew his youth in the timber with the help of the family and flivver, dog and gun. He is

invited to come, is assisted in having a good time, and promptly retaliates by killing the forester's friends and—we must be truthful—every once so often while his wife huddles in a corner of her tent and shivers he does kill one of the forester's enemies as well.

As a means of correcting the abuses which have developed and which are upsetting the natural balance in our forest, there are several things that can be done to bring about more stable conditions. The first of these is a campaign of education among the forest users as to the necessity of maintaining our wild life as far as possible in its present status. All animals should be protected from the promiscuous killing which is now going on, though. We recognize that the destruction of dangerous snakes or of destructive animals, such as the mountain lion, may be very desirable, but the killing for killing's sake of many of our harmless snakes and beneficial mammals is greatly to be deplored. The general public itself very seldom stops to think of the consequences set up by its misuse of the forest, while the majority of the lumberjacks have absolutely no conception of the rôle that biotic factor plays in the development and maintenance of our forest stands.

Whether or not we should encourage trapping in our forests throughout the United States is another matter. Trapping has been responsible for the destruction of many of our fur-bearing animals almost to the point of extinction and this destruction is keeping on at an ever-increasing rate due to the demands of civilization for furs of all kinds to adorn the so-called weaker sex.

A third thing that can be done to maintain our status quo with relation to our smaller animal friends is to set aside areas here and there throughout our forested regions to remain in a state of more or less natural preservation which will serve as homes for those animals that normally are rendered homeless by lumbering and forest sanitation. The presence of snags, old logs and débris of all kinds in these areas is very conducive to maintaining our forest friends through furnishing them suitable hiding places and protection so as to permit their increase and once again make themselves felt as a beneficial influence in our forestry problem.

We are depending upon natural reproduction more and more to restock our denuded areas and if we permit the rodents to gain the ascendency on these areas through the destruction of their natural enemies, we can look for an increase in the cost due to planting that could be avoided to some extent by the protection we may give to the larger mammals. The whole question of biology comes up repeatedly in our forest practices, and nowhere is it so important as in the regeneration of our forest stands.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

TWO KINDS OF CONSERVATION

CONSERVATION is one of those deceptive words that have a double meaning. It is doubly dangerous because its meaning in one case is quite the opposite of its meaning in another case. For instance, in the conservation of our natural resources, a politician with an agate-bearing tongue may say: "I am in favor of the conservation of our petroleum and water power."

Very good. But he and his audience do not always realize that contrary policies must be adopted in the two cases. The conservation of oil means not using it, for all the oil that is used is forever lost. The conservation of water power means using it, for all the water power that is not used is forever lost.

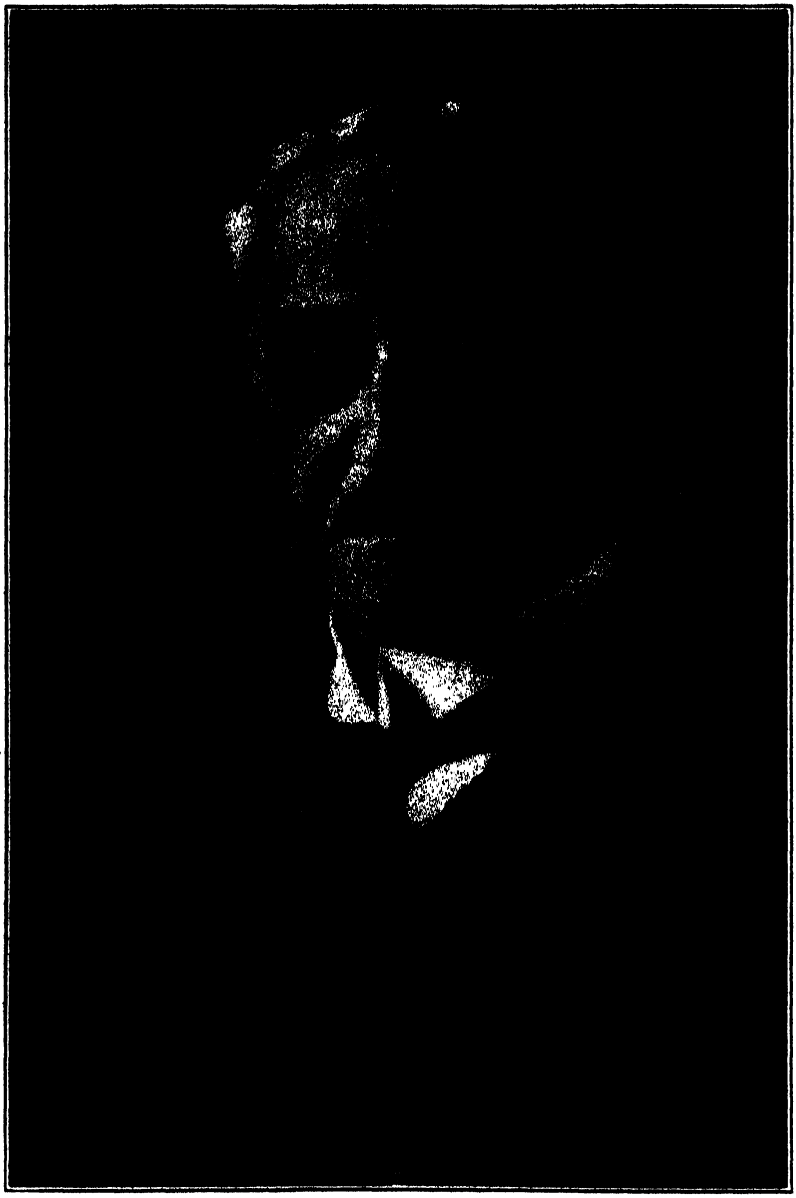
Oil and water do not mix. Both oil and water are limited and inadequate to our needs. But the oil supply is exhaustible while the water supply is inexhaustible. Day by day the sun pumps up water from the ocean and the winds carry it over to the mountains where it falls as rain and fills the streams.

But there is no reason to think that Providence will ever renew the supply of oil that we are so lavishly and wastefully using. Dividing the amount of petroleum left in the earth of our country, estimated at about nine billion barrels, by the amount we withdrew from deposit last year, 745,000,000 barrels, we get 12 as a quotient. That means in a dozen years or thereabouts we will run short of the gasoline and oil that we have been getting from petroleum and that we will have to seek other sources. What those sources will be we do not know but we may be sure that liquid fuel and lubricants will be dearer and more difficult to get in the future. We might get them from oil shale, it is true, but shale has to be mined and extracted while petroleum runs out as soon as its reservoir is tapped.

In some parts of our country we can still see the blazing beacons of natural gas burning all night from our pipes, but most of the communities which formerly have been favored by free use of gaseous fuel have had to fall back on coal.

And there is not enough coal to go around or to last long. Three continents, Africa, South America and Australia, have not enough coal to support an industrial civilization like that of modern Europe. But Europe can not keep up its present consumption of coal for many centuries. The United States and China seem to be the most favored nations in the matter of fossil fuel. They have enough coal to last several thousand years, but that is not forever and we hope it will be but a short chapter in the history of the human race.

Meantime we are wasting the greater part of our coal by inefficient combustion and by toting it back and forth across the country unnecessarily. The miner gets only one crop while the farmer gets a new crop every year. That is because the miner is using up the accumulated carbon of past ages while the farmer accumulates his carbon anew with the aid of each summer's sunshine. One is living on the capital of the world's



JACQUES LOEB

APRIL 7, 1859–FEBRUARY 12, 1924

Member of the Rockefeller Institute for Medical Research and head of its division of general physiology, in whose death the world loses one of its most original and distinguished biologists.

wealth; the other on its interest. The central power house of the solar system has been sending out its energy by radio without any perceptible diminution for some millions of years in the past and seems likely to last at least as long in the future. An impartial Providence has arranged it that the earth revolves as a spit before the fire so that every land receives in turn a share of the sun's rays. Furthermore, every land has been supplied with a supply of carbon and oxygen in exact proportion to its area, since these are free as air.

But only the plants possess the secret of economically separating carbon from oxygen and storing up the former as food and fuel for future use. And even the plants are not good at it although they had practiced the art of manufacturing carbohydrates for many millennia before man came on the scene. The green leaf wastes ninety-nine per cent. of the energy it receives from the sun. But on the one per cent. of the original solar energy that is recoverable on combustion of the combined carbon depends all the life of the world and all the power of the machinery of man except what little he gets from waterfalls and windmills. Water power we are beginning of late to utilize, but wind power we employ less than we used to when it propelled all the ships and ran many of the mills. We have more wind than we want in some places, yet we waste the most of it without a thought of conservation.

The best definition of this ambiguous word I ever saw is that of Acheson: "Conservation consists in the utilization of the inexhaustible for the preservation of the exhaustible." Coal, oil and gas are exhaustible. Water, wind and sunshine are inexhaustible.

CHEMICAL MESSENGERS

WHAT system of government prevails in this body of ours? Is it an autocracy, the one-man rule, such as prevailed in the primitive state and still survives in the army? Or is it a democracy, the equal power of all in politics, regardless of their qualifications, such as is now regarded as the ideal? Or is it an oligarchy, where the superior cells and organs manage the inferior?

Strange to say no system of human government has yet been devised that approaches the organization of the animal organism in character—or in success. The millions of cells, the hundreds of muscles, the dozens of organs, with their infinitely varied powers and functions, are kept in harmonious activity for the good of the whole by some secret system of mutual cooperation which man has not yet learned how to apply to his artificial organism, the state.

The conscious ego can not claim to be the dictator of the physiological realm which he calls his body. He is not even a Premier, but merely a Foreign Minister. He has a certain control over imports and exports, but the Department of the Interior is mostly beyond his jurisdiction. It is his business to keep the body out of fights with others that might result in a stab in the heart or a punch in the stomach, but he is not entrusted with such essential functions as keeping the heart pumping and the stomach digesting. For, important as the mind may think itself, it sleeps at its post for a third of the twenty-four hours and is liable to occasional fits of forgetfulness at any time. It is not the brain that mobilizes the white blood corpuscles whenever an army of microbes invades the body through a breach in the outer wall. Sight is not sharp enough to see a microbe and even if the brain suspected an invasion it would not know how to conscript the corpuscles and despatch them to the front.

DR. FREDERIC A. LUCAS

The distinguished zoologist and museum administrator, who at the age of seventy-two years became director emeritus of the American Museum of Natural History.

All these millions of living cells in brain or brawn or bone have to be kept supplied with food, water and air in amount depending on how they are working and how fast they are growing. The temperature of every part of the body has to be kept constant no matter whether the weather is cold or warm, and the ashes must not be allowed to accumulate in any cell.

Now one would think that such a marvellously complicated coordination of interdependent activities would require a strict system of bureaucratic centralized government. But on the contrary the central government, if there is such, has little or nothing to say about most of the physiological processes. The orders to an organ come from below rather than above. For instance, if an overworked muscle needs more oxygen it does not petition headquarters, but sends orders direct to the heart and lungs to speed up the pumping. If a gang of structural bone workers want more lime or phosphate they do not bother the boss about it but dispatch a message straight to the supply department to import some.

How these multifarious messages could be carried was long a mystery but is now being solved. There are two ways of intercommunication in the body just as there are in the outside world, telegraph and mail. In a telegraphed message nothing travels except the electrical impulse, but in the postal service a material message, the letter, is transmitted. Inside the body signals may be sent by the nerves which play the part of telegraph wires, but it has recently been discovered that there is another and more general system of intercommunication by means of chemical substances sent around through the blood like letters. Professor E. H. Starling, of London, pointed out the importance of these eighteen years ago and named them "hormones" which is Greek for "messengers" and since then many of them have been discovered and some of them manufactured.

The two systems of transmitting orders supplement each other like telegraph and mail. For instance, a man sits down at a dinner table. The eye signals by way of the nerves, "I see food," and a minute later comes confirmation from the nose, "I smell it." At once the saliva begins to pour into the mouth and the gastric juice into the stomach to prepare for the first stages of digestion.

Some time later when the stomach has finished its work three other digestive fluids have to be in readiness. These are secreted by three separate organs, the pancreas, the liver and the intestinal glands, and all these have to be notified to get busy as soon as the first food passes out of the stomach.

In this case the message is conveyed by a hormone called "secretin" which within two minutes after it has been sent into the blood stream sets the three organs to preparing their particular digestive juices.

If we get angry or scared the body has to be put into a state of preparedness for fight or flight, whichever the high authority decides upon. But either will require an extra supply of energy, so the suprarenal glands, without waiting for special orders from headquarters, send a chemical messenger to the heart to pump harder and to the liver to release more sugar into the blood so that no muscle shall be short of fuel in this emergency.

How the sugar is handled depends on another hormone known as "insulin," which has lately been prepared in a form that may be used by diabetics whose pancreas does not work well.

Still more recently comes the announcement of the extraction of a pure

and extremely powerful form of "pituitrin," the secretion of the insignificant pituitary body, that controls the kidneys and capillaries.

The chemist is now able to make "thyroxin," which is secreted by the thyroid gland, and a minute daily dose of this may, as Dr. Starling says, effect "the conversion of a stunted, pot-bellied slavering cretin into a pretty, attractive child."

It is these chemical messengers which in infinitesimal amounts determine whether we shall be tall or short, dark or fair, handsome or ugly, active or sluggish, alert or stupid, cheerful or melancholy, and it is the aim of the chemist to learn how to make them or perhaps similar substances of even greater potency so that he can acquire absolute control over the workings of the human body.

THE PREDICTION OF EARTHQUAKES

Dr. Thomas A. Jaggar, Jr., director of the Hawaiian Volcano Observatory, which is connected with the Weather Bureau of the United States Department of Agriculture, is at present in Washington on an official visit. Dr. Jaggar made a trip to Japan this fall for the purpose of conferring with scientists of that country in regard to the disaster of last August due to earthquake and fire, and also to make observations which might add to the scientific understanding of the phenomena attending such calamities. While here he will prepare a comprehensive report on the subject.

"At the present time there is no known means of predicting an earthquake or a volcanic eruption," stated Dr. Jaggar, when interviewed. "It is believed, nevertheless, that with continued study of this subject we may obtain data which will enable us to send out warnings in time to save lives and, to some extent, protect property. Flood warnings on the great river systems annually save hundreds of human beings and thousands of dollars worth of movable possessions. Increased information about these volcanic and seismic disasters which have occurred should furnish a better understanding of the precautions in building, and in community practices that might be taken by those living in regions subject to such disturbances. We know now, for example, that the important consideration in regard to buildings is not so much what kind of building as how well constructed it is. Many of the wooden Japanese buildings withstood the earthquake perfectly, whereas masonry in numerous places went down with terrible consequences. Fire, however, destroyed hundreds of wooden structures that resisted the earthquake."

The earthquake had very powerful effects on the contour of the Japanese coast and the bays adjacent to it. Landslides occurred which affected the steep shores, and the bottom of the sea was greatly changed. Many other towns in addition to Yokohama and Tokio were damaged, and many other fires were produced. There were a noticeable number of resistant buildings, especially those recently built, but the very old structures, with poor foundations, all went down. Differences in the kind of ground on which buildings stood affected their resistance to shock.

Owing to its high cost, very little earthquake insurance is ever carried to offset possible loss, in spite of the known risk in some regions. There is great need of accurate data on which to base earthquake insurance rates. Further investigation of the subject ought to make it possible to adjust the cost so as to bring this insurance within reach of those who need it.

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LIFE HISTORY OF AN ALPHA PARTICLE FROM RADIUM[1]

By SIR ERNEST RUTHERFORD

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In this lecture I propose to discuss some of the properties of the high-speed α-particle which is ejected spontaneously from radioactive substances. This flying atomic nucleus is not only the most energetic projectile known to us, but it is also an agent of great power in probing the structure of atoms, so that an account of the effects produced by it is of wide scientific interest.

It is now well established that the α-particle expelled from radioactive bodies is in all cases a helium atom, or, to be more precise, the nucleus of a helium atom of mass 4 carrying two positive charges of electricity. It is only when the expelled nucleus is stopped by its passage through matter that it captures the two negative electrons required to convert it into the neutral helium atom. It is natural to suppose that the helium nucleus, which is shot out at great speed from the heavy nucleus of a radioactive atom, formed part of its structure. For some reason, which is not as yet understood, occasionally one of the radioactive nuclei breaks up with explosive violence, ejecting the component helium nucleus with high velocity. It is probable that the α-particle in escaping from the radioactive nucleus acquires part of its great energy of motion in passing through the repulsive electric field surrounding the latter, but at present we do not know the nature of the forces which hold the complex nucleus together, or whether the α-particle is at rest or in orbital motion in the nuclear structure before instability sets in. We know, however, that there is a very wide range of stability exhibited by different radioactive elements. In a sub-

[1] Address before the Royal Institution of Great Britain.

stance like radium A the average life of the radioactive atom before ejection of an α-particle is about 4.3 minutes, for radium itself 2,250 years, while in the case of a very slowly changing element like uranium the average life is of the order of 7,000 million years.

It is known that the α-particles from a given element are all shot out with the same speed, but that this speed varies from element to element. There is apparently a close connection between the velocity of ejection of the α-particle and the average life of the parent element. The shorter the average life of the element, the swifter is the speed of expulsion. This interesting relation between the violence of the explosion and the average life of the element holds in the majority of cases, but it is difficult at present to be at all clear of its underlying meaning. Sir William Bragg long ago showed that the α-particle travels through matter nearly in a straight line, and has a definite range of travel in a substance. This is well illustrated by the tracks of α-particles obtained by Wilson's expansion method. The majority of the tracks are seen to be quite straight, apart from an occasional deflection near the end of the path. At the end of the range the photographic and ionizing effects of the α-particle apparently cease with great suddenness. On account of its great energy of motion, the individual α-particle can be detected by the scintillation it produces in crystalline zinc sulphide, by the effect on a photographic plate, and by special electrical methods, while the beautiful expansion method of Wilson shows the trail of each individual α-particle through the gas.

We are enabled, particularly by the scintillation method, to count the individual particles, and thus we have at our command a method of great delicacy for studying the effects produced by the passage of α-particles through matter. In travelling through a gas the α-particle passes the outer electronic structure of a large number of atoms and liberates electrons, thus giving rise to an intense ionization along the track. The ionization increases to a maximum near the end of the path of the α-particle and then falls rapidly to zero.

A careful study has been made of the law of decrease of velocity of the α-particle in passing through matter by studying the deflection in a magnetic field of a pencil of α-particles before and after its passage through a known thickness of matter. In most of these experiments we employ the α-particles of radium C, which have a range of about 7 cm in air under ordinary conditions. The initial velocity V_0 of these particles is known to be 19,200 kilometers per second, and the reduction of velocity can readily be followed down to about 0.4 V_0. At this stage the emergent range of the α-particles is less than one centimeter, and measurements are difficult, owing to the fact that a beam of α-particles becomes heterogeneous and contains particles moving with different velocities.

For this reason the velocity of the α-particle can not be followed with certainty below 0.38 V_0. We must bear in mind that even at the lowest velocity at which it is possible to detect the α-particle by the scintillation or photographic method, it is still moving at a high speed compared with the positively charged particles generated in an ordinary discharge tube.

It is clear that ultimately the α-particle must be slowed down to such an extent that it captures electrons and becomes a neutral atom, but until recently no evidence of this process of capture of electrons had been obtained. G. H. Henderson[2] has recently added much to our knowledge of this subject by examining the deflection of α-rays in a magnetic field in a very good vacuum. For the success of these experiments it is essential that the apparatus in which the deflection is observed should be exhausted to a very low pressure, corresponding to that required for a good X-ray tube. The reason of this will be seen later. When a narrow pencil of α-rays was deflected in a magnetic field two bands were observed on the photographic plate: one the main band, due to ordinary α-particles carrying two positive charges, and another midway band, which he supposed to consist of particles which had captured one electron, *i.e.*, to singly charged helium atoms. At low velocities he also obtained evidence of the existence of neutral α-particles resulting from the capture of two electrons by the helium nucleus. In these experiments Henderson employed Schumann plates, where the film is so thin that low velocity particles produce as much or more photographic effect than the swifter particles.

I have repeated these experiments by the scintillation method, and confirmed the deduction of Henderson. By observing the

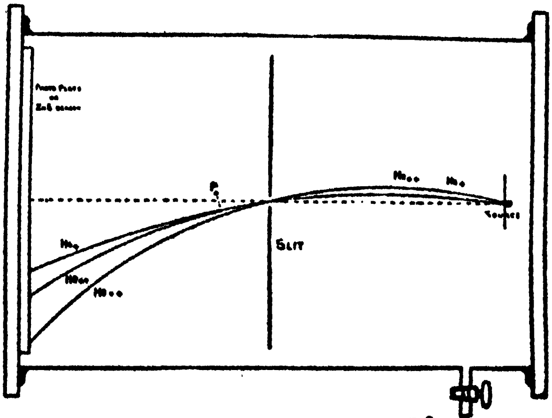

FIG. 1

[2] Proc. Roy. Soc., A, cii, p. 496, 1922.

deflection of the midway band in an electric as well as in a magnetic field, I find there is no doubt the particles composing the midway band consist of particles of mass 4 and charge 1—*i.e.*, to singly charged helium atoms which have the same speed as the doubly charged particles comprising the main band.

Some recent experiments have been made by me to throw light on the conditions under which the flying α-particles may gain or lose an electron. The general arrangement of the experiment is shown in Fig. 1. A fine platinum wire coated with radium B + C, by exposure to the emanation (radon), serves as a nearly homogeneous source of α-rays, since the α-particles are emitted only from the atoms of radium C, which are too few in number to form a film on the platinum of even one molecule thick. The α-rays from this source pass through a narrow slip about 0.3 mm wide and fall on a screen of zinc sulphide. The distribution of α-particles on the screen is determined by the scintillation method in a dark room, using a microscope outside the box. The vessel containing the source and screen is completely exhausted by means of a Gaede and mercury diffusion pump, and if necessary the residual pressure can be measured by a Macleod gauge. The box is placed between the plane pole pieces of a large electromagnet so that the pencil of α-rays is bent in the direction shown in the figure. Usually the distance between the source and screen was 16 cm, with the slit midway. The whole path of the rays was exposed to a nearly uniform magnetic field, and the deflection of the pencil of rays was proportional to the strength of the magnetic field. Under normal experimental conditions the pencil of α-rays from the bare radium C wire was bent a distance on the screen of about 15 mm from the zero position without field. The field of view of the microscope was sufficient to take in the depth of the whole pencil of α-rays without the field.

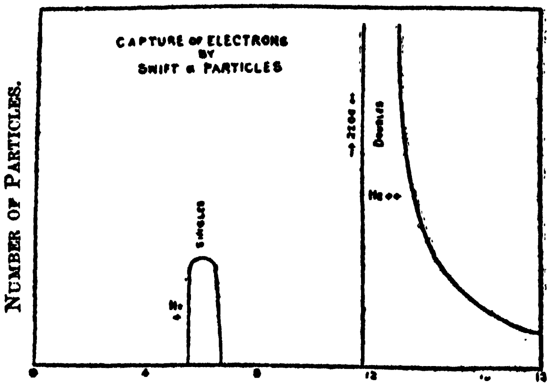

FIG. 2.—DEFLECTION IN MM BY MAGNETIC FIELD

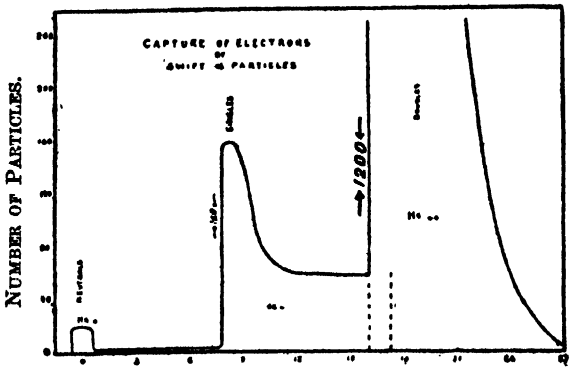

FIG. 3.—DEFLECTION IN MM BY MAGNETIC FIELD

Special precautions were taken to prevent contamination of the screen by the escape of active matter from the wire in a low vacuum. It must be borne in mind that the type of wire source employed always introduces some heterogeneity in the beam of α-rays even from the uncovered source. This is due to the escape from the back of the wire of α-particles which are reduced in velocity in passing through the material. This effect is clearly manifest when the pencil of α-rays is deflected by a magnetic field; for in addition to the main band of α-rays there is always a distribution of particles extending beyond the main beam. The intensity of this heterogeneous beam at any point is generally less than 1 per cent. of the main beam, and does not seriously interfere with the accuracy of the deductions discussed in this lecture.

In Figs. 2 and 3 are given illustrations of the distribution of singly and doubly charged α-particles along the zinc sulphide screen. Fig. 2 shows the result when a thickness of mica corresponding in stopping power to 3.5 cm of air is placed over the source. The main band, due to He_{++} particles, is sharply defined on the high velocity side, but there is evidence of some heterogeneity produced in the beam by its passage through the mica. As we should expect, the midway band (He_{+} particles) lies exactly between the zero position and the main band, and contains only about 1/55 of the particles in the main beam. Fig. 3 shows the distribution when the thickness of mica is increased to correspond to a stopping power of about 6 cm of air. Both the main and midway bands are no longer sharply defined as in the first case, but each consists of particles with a considerable range of velocities. The relative number of He_{+} and He_{++} particles is about 1/8 for the swifter particles, but this ratio increases with decreasing velocity. The midway band extends and joins the main band where it can no longer be followed. The brightness of the scintillations due to He_{+} particles falls off ob-

viously and continuously from A to B. At this stage, too, some neutral particles make their appearance. This is shown by the He_0 band, which is not deflected by a magnetic field, but its intensity is small compared with that of the midway band. There is also a sparse distribution of faint particles between the neutral and midway band, probably due in part to scattering of the α-particles by the edges of the slit and possibly in part due to recoil atoms of oxygen and other elements constituting the mica. The distribution of the charged and uncharged helium particles for a still lower velocity will be seen in curves A, B, Fig. 4, which will be referred to later. It is seen that the relative number of He_+ to He_{++} particles has increased; similarly, the relative number of neutral particles is much greater.

We may now consider the interpretation to be placed on these observations. It is clear that the particles emerging from the mica consist of doubly charged, singly charged, and neutral particles, but the relative number of these three types varies markedly with the stopping power of the mica plate. We may suppose that the α-particle in passing through the outer electron structure of the atoms in its path occasionally removes and captures an electron. This electron falls into a stable orbit round the doubly charged helium nucleus and moves with it.

This singly charged atom will, however, have only a limited life, for in passing through other atoms the electron is knocked off and the singly charged α-particle reverts back to the doubly charged type. This process of removal is analogous to the ordinary process of ionization where an electron is ejected from an atom by a collision with an α-particle; for as a singly charged particle can remove electrons from another atom, so there is a chance that the He_+ particle should lose its attendant electron. We may thus consider that two opposing processes are at work, one resulting in the capture of an electron and the other leading to its removal. From the data

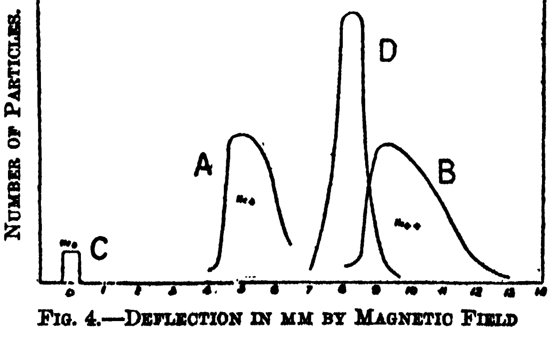

FIG. 4.—DEFLECTION IN MM BY MAGNETIC FIELD

given later it will be seen that this process of capture and loss may repeat itself more than a thousand times in the flight of an α-particle, so that the average path travelled by an α-particle before capture of an electron or before loss of the captured electron is small compared with the total distance of travel of the α-particle before it comes to rest. It is clear from this, for a given velocity of α-particle, that there must be a momentary equilibrium between the number of He_+ and He_{++} particles such that, on the average, the number of captures in a given small distance is equal to the number of losses.

It is very convenient to suppose that for a given velocity each He_{++} particle has a mean free path λ_1 cm in the material before it captures an electron, and the He_+ particle a mean free path λ_2 cm before it loses its attendant electron. No doubt some of the individual particles travel distances much shorter or longer than this mean distance before either capture or loss, but in considering a large number of particles we may suppose there is an average distance traversed before capture or loss, to be called the mean free path.

When N_1 He_{++} particles traverse a small distance dx of a material the number which capture electrons is N_1dx/λ_1. If N_2 He_+ particles are present the number which lose an electron is N_2dx/λ_2. But we have seen that when an equilibrium is set up, the number of captures in a given distance must equal the number of losses. Equating these two expressions, it is seen that $N_2/N_1 = \lambda_2/\lambda_1$, or, in other words, the relative number of He_+ to He_{++} particles is proportional to the ratio of the mean free path for loss to that for capture. Since by the scintillation method the ratio N_2/N_1 can be measured for any velocity, by using different thicknesses of absorber we can thus determine the ratio of the mean free paths for capture and loss for any velocity.

The actual value of the mean free path λ_2 of the He_+ particle before it loses its electron can be directly determined by experiment. Suppose the microscope is focussed on the midway band of Fig. 2 and the number of scintillations per minute observed in a good vacuum. If the pumps are shut off and a small quantity of air or other gas is introduced into the apparatus, the number of scintillations is found to diminish with increasing pressure of the air until the band has completely disappeared. This takes place at quite a low pressure of air: for example, for a pressure of about ¼ mm in the box.

The explanation of this result is obvious. The He_+ particles which escape from the mica occasionally collide with an atom of the gas in its path, and the electron which it captured in passing

through the mica is removed. In such a case the He_+ becomes again an He_{++} particle, and the latter is twice as easily deflected in a magnetic field as the former. Suppose the collision occurs for the first time at the point P (Fig. 1). The particle after losing its electron travels along a new path shown in the figure, and the particle no longer strikes the part of the screen viewed by the microscope. It is found that the number of scintillations seen in the microscope falls off according to an exponential law as the pressure of the gas is raised. Such a result is to be expected, and from this data the average distance which the He_+ particle traverses before it loses its electron can be simply deduced. Certain small corrections are necessary to take into account the finite width of the band of scintillations as seen in the microscope, but we need not enter into details at this stage. It is convenient to express the mean free path λ_2 in air of the He_+ particles, not as the average length of path traversed in the rarefied gas before loss, but as the distance traversed in the same gas at standard pressure and temperature. For example, in a certain experiment the mean free path in air of the particle was found to be 12 cm at a pressure of 0.040 mm; this corresponds to a mean free path of 0.0063 mm at standard pressure and temperature.

In this way the mean free path in air before loss of an electron has been measured for different velocities, and it has been found over a considerable range that the mean free path varies directly as the velocity of the α-particle, so that the mean free path becomes shorter as the velocity of the α-particle diminishes. Since we may regard the loss of an electron from the singly charged particle as the result of a process of ionization, such a relation is to be expected, and indeed, if we take into account the strong binding of a single electron by the He_{++} nucleus, the mean free path for loss is of the same order as that calculated from considerations of the number of ions per cm produced by the α-particle in air and other gases. Comparisons have been made of the mean free path in air with that in hydrogen and helium. Its value is 4 to 5 times longer in hydrogen and more than 5 times longer in helium.

Now that the mean free path λ_2 is known, the value of λ_1 for capture can be deduced if the ratio N_2/N_1 is also known. A difficulty, however, arises at this point. In order to measure the ratio N_2/N_1 it is necessary that the active source should be covered with mica or other solid material. Gas can not be used conveniently. It was found, however, that the ratio N_2/N_1 was the same within the limits of error whether the α-particles were reduced in velocity by passage through celluloid, mica, aluminium or silver. For this purpose the mica was kept the same and a very thin sheet of the substance under examination spread over it. The thickness of the sheet was suffi-

cient to set up a new equilibrium between the singly and doubly charged particles, but not sufficient to alter materially the velocity of the ionizing rays.

Since the value of the ratio N_2/N_1 suffers no appreciable change for absorbers of such different atomic weights, we may safely conclude that the ratio for a hypothetical sheet of solid air would be the same as for mica.

We have now all the data required to determine the values of λ_1 and λ_2 corresponding to α-particles of different velocities. The results are given in the following table for three different velocities. The mean free paths are expressed in terms of millimeters of air at standard pressure and temperature. V_0, the maximum velocity of the α-particles from radium C, is 1.9×10^9 cm per second.

Velocity V in terms of V_0	$\lambda_2/\lambda_1 = N_2/N_1$ for Mica	Mean Free Path λ_2 for Loss in Air	Mean Free Path λ_1 for Capture in Air
0.94	1/200	0.011 mm	2.2 mm
0.76	1/67	0.0078 mm	0.52 mm
0.47	1/7.5	0.0050 mm	0.037 mm

It has been seen that the mean free path for loss varies directly as the velocity, and thus only alters in a ratio of about 1 to 2 over the range of velocities given in the table. On the other hand, the ratio λ_2/λ_1 increases very rapidly with diminution of velocity varying approximately as V^{-5}. From this it follows that λ_1 varies as V^6, thus decreasing by a factor of 60 or more when the velocity is halved.

From these data and relations it can easily be calculated that the mean free path for capture should be equal to that for loss for a velocity about 0.3 V_0, and for this speed the numbers of He_+ and He_{++} particles should be equal.

The actual value of the velocity for equality of the two types in a special experiment was found to be 0.29 V_0, in good agreement with the calculated value. It is a difficult matter to determine the values of λ_1 and λ_2 for velocities less than 0.3 V_0, for not only are the scintillations weak in intensity and difficult to count with accuracy, but also the issuing rays are very heterogeneous and no longer show well-defined edges on the high velocity side. It was, however, noted that the ratio N_2/N_1 rapidly increased below the velocity 0.3 V_0.

We have so far dealt with the equilibrium between He_+ and He_{++} particles. It is clear, however, that similar considerations apply to the equilibrium between singly charged and neutral helium

particles at low velocities of the α-particle. It was noted that the neutral particles appear prominently after the rays have passed through mica of 6 cm stopping power, but no doubt they could be detected for still lower stopping power. These neutral particles, of course, produce scintillations, but of an intensity corresponding to an α-particle of low velocity. These neutral particles probably lose and regain an electron many times before they are stopped in the zinc sulphide or other absorbing material. This effect was shown by introducing gas at low pressure into the apparatus, when the scintillations due to the neutral particles diminished in number and ultimately vanished. The explanation of this is similar to that given for the disappearance of the He_+ band, for the neutral particles occasionally lose an electron in passing through the gas and are then deflected away from the zero position by the magnetic field.

It was estimated that the mean free path in air for conversion of neutral helium particles to singly charged particles was about 1/600 mm. No doubt this is an average for particles of very different velocities which may be present in the neutral band.

For the higher velocities we have to deal mainly with the interchange $He_{++} \rightleftarrows He_+$. For velocities less than 0.5 V_0 the interchange $He_+ \rightleftarrows He_0$ also comes in and becomes all-important for velocities less than 0.3 V_0. No doubt, as Henderson has shown, at still lower velocities most of the He_{++} particles disappear and the He_0 and He_+ particles predominate.

At these low velocities counting scintillations becomes very difficult and uncertain, and the photographic method, as used by Henderson, is preferable. It will be a matter of very great interest to examine whether the relative numbers of the three types of particles alter when the α-particles are slowed down by passage through different materials. This side of the work is being attacked by Mr. Henderson in the University of Saskatchewan.

There is one very interesting point that may be considered here. It has been shown that these singly and doubly charged α-particles are always present after the α-rays have passed through mica or other absorber; but are there any singly charged particles present when α-particles escape from a wire coated with an infinitely thin deposit of active matter? This was first tested for a platinum wire coated with a deposit of radium B + C by exposure to the radium emanation, when it was found that singly charged helium atoms were present in about the equilibrium ratio for this velocity. This was a rather surprising observation, but it was thought it might result from the fact that by the recoil from radium A the radium B particles penetrate some distance into the material of the wire. Under these conditions many of the α-particles expelled from

radium C have to pass through a small but appreciable thickness of matter before escape from the wire, and might thus capture electrons. This explanation seemed unlikely because the average distance penetrated by the recoil atom is only a minute fraction of the mean free path for capture at such high velocities of the α-particle. The experiment was tried with a nickel wire on which radium C had been deposited on the surface by the well-known method of dipping the wire in a hot solution of radium C. In this case the difficulty due to recoil is absent, but the number of singly charged particles was the same as before.

It is very significant that the relative number of singly and doubly charged particles is about the equilibrium ratio to be expected when the wire, after being activated, is coated with an appreciable thickness of copper or other material. We can scarcely suppose that singly as well as doubly charged particles are actually liberated from the radioactive nucleus itself, for even if it be supposed that an α-particle with an attendant electron is expelled, the electron must be removed in escaping through the very powerful electric field close to the nucleus. It is much more probable that the doubly charged α-particle in passing through the dense distribution of electrons surrounding the radioactive nucleus occasionally captures an electron, and that the process of capture and loss goes on to some extent in escaping from the radioactive atom. This seems at first sight rather unlikely when we consider the relatively large number of atoms an α-particle ordinarily passes through before equilibrium between capture and loss is established, but it is well known that the chance of effective electronic collisions appears in general to be greater for a charged particle expelled from the central nucleus than for a similar particle passing from outside through the electronic distribution of an atom. It may be that those electrons the orbital motion of which round the nucleus is comparable with the speed of the α-particle are particularly effective in causing capture or loss.

So far we have dealt mainly with the distribution in a magnetic field of the particles in a vacuum after their escape from a mica surface. Some very interesting points arise when the distribution is examined in the presence of sufficient gas to cause a rapid interchange of capture and loss along the path of the α-particle in the gas. This is best illustrated by a diagram, Fig. 4, in which the results are given for α-particles escaping through mica with a maximum emergent range of about 4 or 5 millimeters in air. Curves A and B give approximately to scale the distribution of He_+ and He_{++} particles in a vacuum, while C gives the relative number of neutral particles under the experimental conditions. Suppose

now sufficient air is introduced into the vessel to cause many captures along the gas, but yet not enough to reduce seriously the velocity of the α-particles. The first salient fact to notice is that the distributions A, B, C vanish and there remains a distribution of particles (curve D) about midway between A and B. This band is narrower than either A or C, and its height at the maximum much greater than either. It is evident that the particles have been compressed into a band of much narrower width than the normal distribution in curve B.

This is exactly what we should expect to happen. The swifter particles present suffer less capture than the slow; consequently the average charge of the swifter α-particles along the gas is less than 2*e*, and their deflection is less than the swiftest particles shown in curve B. On the other hand, the slower α-particles have an average charge nearer 1*e* than 2*e*, and are relatively still less deflected than the swifter particles. It is thus clear that the resulting distribution of particles with air inside the vessel will be concentrated over a much narrower width than the main band of He_{++} particles. From calculation based on the laws of capture and loss, the width of the band under the experimental conditions can be deduced, and is found to be in good accord with experiment. It will be seen to be significant that similar results have been observed for hydrogen under corresponding conditions.

General Discussion of Results

Attention may now be devoted to a consideration of the results so far obtained and the possibility of their explanation on present views. In the first place, it is important to emphasize the large number of capture and losses that occur during the flight of an α-particle from radium C. While the mean free path of the α-particle from radium C of 7 cm range is about 3 mm in air, its value rapidly decreases with lowering of the velocity of the α-particle, and is probably about 0.0015 mm for a velocity of 0.3 V_0. It is not difficult to calculate that not far short of a thousand interchanges of charge occur during the path in air of a single particle between velocities V_0 and 0.3 V_0. While the data so far obtained do not allow us to calculate the number of interchanges of charge that occur between velocities 0.3 V_0 and 0, it seems probable that the number is considerably greater than a thousand. We have already pointed out that for low velocities the interchange $He_+ \rightleftarrows He_0$ predominates. When we consider the rapidity of interchange of charges of the α-particle at average velocities, it seems clear that we can not expect to observe any appreciable difference in power of penetration between a beam of rays of the same velocity, whether

consisting initially of singly or doubly charged particles. It is clear that a singly charged particle after penetrating a short distance is converted into a doubly charged particle, and vice versa, and that the effects due to the two beams should be indistinguishable. Henderson tried such absorption experiments, using the photographic method, but with indefinite results.

When an α-particle captures an electron, the latter presumably falls into the same orbit round the helium nucleus as that which characterizes an ionized helium atom, *i.e.*, an atom which has lost one electron. When the α-particle with its attendant electron passes swiftly through the atoms of the gas in its path, it will not only ionize the gas but will also occasionally be itself ionized, *i.e.*, will lose its attendant electron. When we take into account the strong binding of the first electron to the helium nucleus—ionization potential about 54 volts—the mean free path for loss of the captured electrons in air is of the right order of magnitude to be expected from considerations based on the ionization by the α-particle per unit path in air. While we can thus offer a quantitative explanation of the mean free path for loss observed experimentally, the inverse problem of the capture of an electron by the flying α-particle presents very great difficulties.

In the actual case, the α-particle is shot at high speed through gas molecules which for all practical purposes may be supposed to be at rest. For convenience of discussion, however, it is preferable to make an equivalent assumption, namely, that the α-particle is at rest and the gas molecules stream by it with a velocity equal and opposite to that of the α-particle. Now the maximum velocity of an α-particle from radium C is equivalent to that gained by an electron in falling freely between a difference of potential of about 1000 volts; so that the electrons comprising the molecules of air or other gas have a velocity of translation numerically equal to this. For brevity, it is very convenient to speak of this velocity or energy as that due to a "1000-volt" electron.

When the electrons in an atom pass close to the α-particle, one of them may be removed from the parent atom by the collision, energy being required for this process. The ionization potential for oxygen or nitrogen is about 17 volts, which is a very small quantity compared with the energy of translation of a 1000-volt electron.

If we consider the forces involved between an α-particle and moving electron as of the ordinary electrostatic type, the electron will describe a hyperbolic orbit round the nucleus, the angle of deflection of the path of the electron resulting from the collision depending on the nearness of the approach of the electron to the nucleus. On ordinary dynamics, the electron will never be captured in such a collision if there is no loss of energy by radiation. If

capture for some reason results from the collision, it means that an amount of energy corresponding to at least a 1000-volt electron has in some way been got rid of. This loss of energy may be supposed to be due to some interaction between the α-particle and colliding nucleus with its attendant electrons, or to the loss of energy by radiation during the collision. The first supposition seems at first sight plausible, for we know that the innermost electrons of oxygen or nitrogen are strongly bound and require energy of the order of 500 volts to remove them from the atom. But there is one very strong and, it seems to me, insuperable objection to this view.

I have found that the deflection in a magnetic field of a pencil of α-particles passing through a suitable pressure of hydrogen is similar to that shown in curve D, Fig. 4, for air. This shows that the α-particle passing through hydrogen captures electrons of energy about 120 volts to about the same degree as in air. Now we know that the electrons in the hydrogen atom or molecule are lightly bound, and an energy of not more than a 30-volt electron, suitably applied, would entirely separate the component nuclei and electrons in the hydrogen molecule. In the case of hydrogen, therefore, we can not hope to account for the requisite loss of energy, which for the experiment considered is about 100 volts. If these experiments with hydrogen are correct, and are valid for all velocities of the α-particle, we are driven to conclude either that some unknown factors are involved in the capture, or that the loss of energy of the electron must be ascribed to radiation. In such a case capture of an electron may be regarded as the converse of the photo-electric effect, where radiation falls on matter and swift electrons are ejected from the matter. In the case under consideration swift electrons are shot towards a charged nucleus and an occasional electron is captured with the emission of energy in the form of radiation. On such an hypothesis the radiation of energy from an α-particle passing through a gas due to the frequency of capture is very great, amounting to about 3 per cent. of the total energy of the α-particle. This seems to be an unexpectedly large amount, but can not be ruled out as impossible in the present state of our knowledge.

In the discussion of this very thorny question, I have confined myself mainly to the case of capture by the swift α-particle, where the difficulties of explanation are much greater than for capture at slower velocities. Our information is at present too incomplete to give a decisive answer, but there seems to be no doubt that the unexpected frequency of capture of electrons by swift α-particles raises many new and interesting questions of the nature of the processes that can occur in collisions between electrons and matter.

I need scarcely say that the phenomena of capture and loss are not confined to the α-particle, but are shown by all charged atoms in

swift motion through a gas, and were long ago observed in the case of positive rays. On account, however, of the high velocity of the α-particles and the ease of their individual detection, the process of capture and loss can be studied quantitatively under simpler and more definite conditions than in the case of the electric discharge through a gas at low pressure.

On this occasion I have devoted my attention to the most recent additions to our knowledge of the life history of the α-particle. This knowledge has been obtained from the study of the rapid interchange of charges when an α-particle passes through matter. I have only incidentally referred to the numerous collisions with electrons along the track of the α-particle which result in dense ionization. I have omitted any consideration of those rare but interesting encounters in which an α-particle is deflected through a large angle by a close collision with a nucleus. I have omitted, too, the still rarer encounters that may result in a disintegration of an atomic nucleus like that of nitrogen or of aluminium. We have seen that an α-particle has an interesting history. Usually it is retained as an integral and orderly part of a radioactive nucleus for an interval of more than a thousand million years. Then follows a cataclysm in the radioactive nucleus; the α-particle gains its freedom and lives an independent life of about one hundred millionth of a second, during which all the incidents referred to in this lecture occur.

If we are dealing with a dense and compact uranium or thorium mineral, the α-particle after acquiring two electrons and becoming a neutral helium atom may be imprisoned in the mineral as long as the mineral exists. The occluded helium can be released from the mineral by the action of high temperature, and after removal of all other gases can be made to show its presence by the characteristic brilliant luminosity under the stimulus of the electric discharge. In the circumstances of such an experiment only small quantities of helium are liberated. Large quantities of helium, sufficient to fill a large airship, have, however, been isolated from the natural gases which escape so freely from the earth in various parts of Canada and the United States. It is a striking fact that every single atom of this material has in all probability had the life history here described.

ADDENDUM[3]

It may be of interest to give here a brief review of some additional facts in connection with the α-particle, brought to light in recent years. It has long been known that α-particles, although projected from the source at the same speed, travel unequal dis-

[3] This did not form part of the discourse, but it may usefully supplement one or two of the points surveyed in the lecture.

tances through a gas. For example, the maximum distance travelled by the α-particles from radium C in air is 7.04 cm at 760 mm and 15° C., the minimum distance is about 6.4 cm, and the mean distance about 6.8 cm. Some "straggling" of the α-particles is to be anticipated on general grounds, since the α-particle loses its energy mainly in liberating electrons from the atoms of matter in its path. On the laws of probability one α-particle may meet more atoms and liberate more electrons than another, and thus lose energy at a faster rate. The amount of straggling observed is, however, much greater than can be accounted for in this way, and the occasional large deflections of the α-particles due to nuclear collisions are so rare, except near the end of the range, that they do not seriously influence the final distribution.

Henderson has suggested that the property of an α-particle of capturing and losing electrons will introduce a new factor in causing straggling. No doubt this is the case, but the rates of capture and loss observed appear to be too rapid to account entirely for the discrepancy between theory and experiment. Another interesting suggestion has been made by Kapitza to account for the magnitude of this straggling. From the experiments of Chadwick and Bieler on the collision between α-particles and hydrogen nuclei, it has been deduced that the α-particle or helium nucleus has an asymmetrical field of force around it. This asymmetry of the electric field must become small at the distance of the orbits of the electrons in the neutral helium atom, but may be sufficient to fix the plane of the orbit of an electron relative to the axis of the helium nucleus.

Suppose that the α-particles liberated from a radioactive source, have their axis orientated at random, and that the direction of the axis of each individual particle remains unchanged during its motion. In some cases, for example, the captured electron will describe an orbit of which the plane is nearly in the direction of motion of the α-particle; in other cases nearly perpendicular to it. It is to be expected, however, that the chance of losing the captured electron by collision will be greater in one case than the other; or, in other words, the mean free path of the singly charged α-particle before loss of its electron will be different in the two cases.

On this view it is to be anticipated that one group of α-particles will lose energy faster than the other, and the ranges will be different. In order to test whether α-particles show the individual differences to be expected on this theory, Kapitza has photographed in the Cavendish Laboratory the tracks of a number of α-particles by the Wilson expansion method, using a strong magnetic field of about 70,000 Gauss, produced by a momentary current of great intensity. The magnetic field was sufficiently strong to cause a marked bending of the track of the α-particle. It was found that the curvature of the tracks at equal distances from the ends showed marked varia-

tions. Before any definite decision can be reached a large number of tracks obtained in this way must be carefully measured up and allowance made for the sudden bends which occur due to a nuclear collision with the atoms of nitrogen or oxygen. The frequency of these bends near the end of the range complicates the interpretation of the apparent curvature which is measured. The experiments, which are still in progress, are difficult and require great technical skill, and it will be a matter of much interest if any definite asymmetry in the orbits of the singly charged α-particles can be established by this or other methods. If such an asymmetry exists, it must influence to a small extent the arrangement of the two electrons round the helium nucleus and possibly their spectrum.

During the past two years Blackett, in the Cavendish Laboratory, has made a careful examination of the frequency of occurrence of sharp bends or forks in the tracks of α-particles near the end of their range in air and other gases. For this purpose a simple form of Wilson expansion chamber, of the type designed by Shimizu, has been used, and each track has been photographed in two directions at right angles to each other to fix the angle of the forks in space. A large number of photographs have been taken, and the frequency of the forks has been examined in different gases, particularly in the last centimeter of the range of the α-particle. Assuming that these forks arise from nuclear collisions, it is possible to deduce from the experimental data the variation of velocity of the α-particle near the end of its range. It is known from the work of Geiger and Marsden that the maximum velocity v of the α-particles of emergent range R is given by $v^3 \propto R$, when R is not less than one centimeter. Blackett finds that this relation between velocity and range no longer holds near the end of the track, but is replaced by a relation of the form $v^{1 \cdot 5} \propto R$.

In the course of these experiments a number of well-defined forks have been photographed in hydrogen, helium, air and argon by Blackett, and also by Auger and Perrin in Paris. By measuring the angles between the original direction of the α-particle and the direction of the colliding particles after collision, the accuracy of the laws of impact can be directly tested. The results are found, within experimental error, to be in agreement with the view that the impacts are perfectly elastic, and that the conservation of energy and of momentum hold in these nuclear collisions. Conversely, by assuming that the impacts are perfectly elastic, it is possible to deduce the mass of the recoil atom in terms of the α-particle of mass 4.00. For example, a fork in helium gave the mass of the recoil atom 4.03, and a fork in hydrogen gave the mass of the recoil atom 1.024. In a collision between the α-particle and a helium nucleus the angle between the forks should be exactly a right angle; the value measured was 89° 45′.

ONE EMBRYO FROM TWO EGGS[1]

By Professor T. H. MORGAN

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EGGS are occasionally found that are twice as large as the normal eggs of the species. They are supposed to arise from the union of two eggs. They develop into embryos that are twice as big as normal embryos. The origin of these "giant eggs" is of peculiar interest to embryologists, and their occurrence has led to several attempts to unite two eggs by artificial means.

The inclusion of two yolks in a single shell that is not infrequently observed in hens' "eggs" is quite a different affair. These "double eggs" of the hen are only two eggs (yolks) that have been set free from the ovary at the same time, and have become enclosed in a common albumen and shell. They give rise to two embryos, but these are not united, and both die, as a rule, before hatching, although occasionally one of them—the one nearer the large end of the egg—may survive because it is so placed that this chick may make use of the air in the air chamber at the large end of the egg during the final stages of development.

Fusion of two blastulas of sea urchins has also been observed and even experimentally brought about. The results are less instructive than when the union has taken place before development begins, but the facts are interesting in so far as they furnish evidence as to what extent readjustments can take place after the development has already been carried forward to the blastula stages. In point of time, moreover, these cases were the ones first recorded.[2] An account of these fused embryos will be given elsewhere.

The artificial union of parts of amphibian embryos will also be considered at another time in connection with experiments relating to grafting, since in most of these cases the development has progressed so far that the problem of readjustment involves little more than the actual union of the cut surfaces that are brought together.

1 Chapters from "Experimental Embryology," IV.

2 The earliest account of the union of two embryos into monstrous double forms is that of Lacaze Duthier, in 1875. He observed such union in the embryos of the mollusc, *Philine aptera.* Metchnikoff, in 1886, recorded the fusion of two or three blastulas of the hydrozoon *Mitrocoma annae.* Korschelt ('95) states that the eggs in the body cavity of an annelid Ophryotrocha are sometimes fused. The union of the blastula stages of the sea urchin observed by Morgan ('95), Driesch ('00), Bierens de Haan ('13) and Goldfarb ('14) will be considered in another connection.

In Triton, however, Spemann ('16, '18) has succeeded in grafting pieces of blastula stages together, and has succeeded in incorporating a piece of one embryo into another, even when the two belong to different species. These results will also be described in connection with grafting experiments on embryos.

In general it may be said that the results obtained from fused eggs or embryos have not solved any of the larger problems of development, but the results have been useful in studying special problems and have broadened our ideas concerning some of the possibilities of regulation between two systems each alone adjusted to produce only a single individual.

Double Eggs of Sea-Urchins

The development of giant eggs of sea-urchins has been studied by Boveri ('01, '14), Herbst ('14) and Bierens de Haan ('13). Such eggs (Fig. 2, b) furnish an opportunity to study experimentally an important problem, namely, the relative influence of chromatin and protoplasm in the development of *hybrid* larvae. The giant eggs of the sea-urchin have, as a rule, a single nucleus whose surface is twice that of the surface of the nucleus of the normal egg. Twice the normal number of chromosomes are present. The origin of these eggs is unknown. It has been suggested that they may arise from a failure of the protoplasm of a young germ-cell to divide at a time when its chromosomes divide, or that they arise from the fusion of two germ-cells with subsequent fusion of their nuclei. A double cell, formed in either of these ways, would, it is assumed, grow to double the size of the normal egg. It has also been suggested that failure of one or both of the polar bodies to be extruded would produce an egg with a nucleus of double size—a nucleus with the diploid number of chromosomes, but it does not follow that such an egg would then grow to double size, since the polar bodies are formed only when the growth of the egg has come to a standstill.

Bierens de Haan ('13) records that in certain individuals and in certain years, and at certain time in the year, giant sea-urchin eggs are not so rare as at other times. One female (Sphaerechinus) had hundreds of such eggs, while other individuals had none. These giant eggs may be fertilized, and if the sperm is much diluted polyspermy may be avoided. The cleavage is normal, giving rise, at the 8-cell stage, to the characteristic four micromeres, etc. The embryo develops at the normal rate. Large blastulae and plutei result. The number of cells is the same as in the normal embryo, but the cells are twice as large. A giant blastula of Sphaerechinus, for example, has about 32 mesenchyme cells, and the same number are found in the normal blastula. The normal egg of

Sphaerechinus, according to Baltzer, contains 20 chromosomes; after fertilization 40. The fertilized giant egg contains, according to Bierens de Haan, 60–63 chromosomes. Forty of these have probably come from the egg (diploid) and 20 from the sperm.

Herbst ('14) has studied hybrids that have been produced by fertilizing the giant eggs of Sphaerechinus (Fig. 2, b) by the sperm of Stronglyocentrotus. A normal pluteus of Strongylocentrotus is shown in Fig. 1, a, and of Sphaerechinus in Fig. 1, b. Two hybrids from normal eggs are shown in Figs. 2, a^1, a^2, and two hybrids from giant eggs in Figs. 2, b^1, b^2. It is obvious at a glance that the latter are more like the Sphaerechinus type (Fig. 1, b) than like the hybrid from normal eggs (Fig. 2, a^1).

Herbst has analyzed in detail the characters of the larval skeleton of these two kinds of hybrids. The skeletons are quite variable, but in nearly every respect the skeleton of the hybrid giant-pluteus is more like that of the Sphaerechinus pluteus than like that of the hybrid from normal sized eggs.

Herbst records more variability in the size of the nuclei in the giant eggs than was observed by Bierens de Haan. His measurements show that there are two, possibly three, categories of nuclei in regard to size. There are giant eggs whose nucleus has twice the volume of those of the normal nuclei, and eggs that have four times the volume of the normal. Possibly the latter, he suggests, are

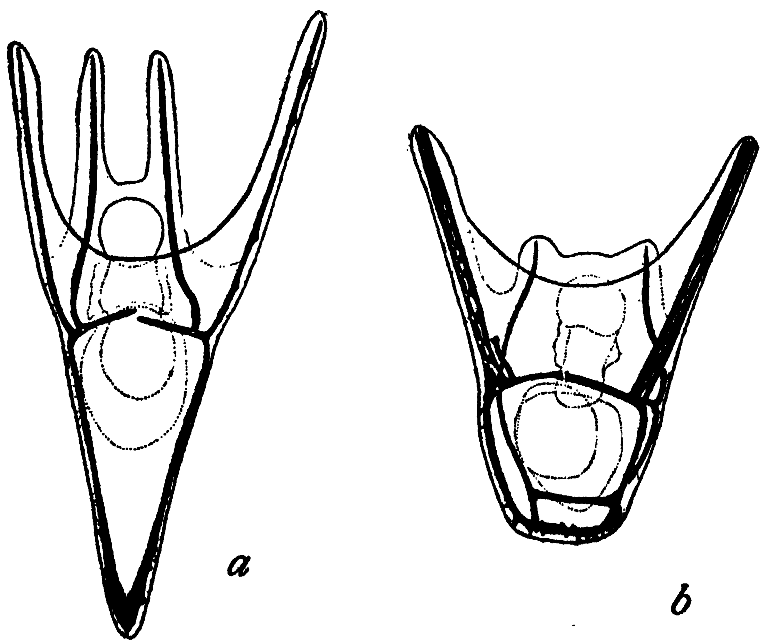


FIG. 1

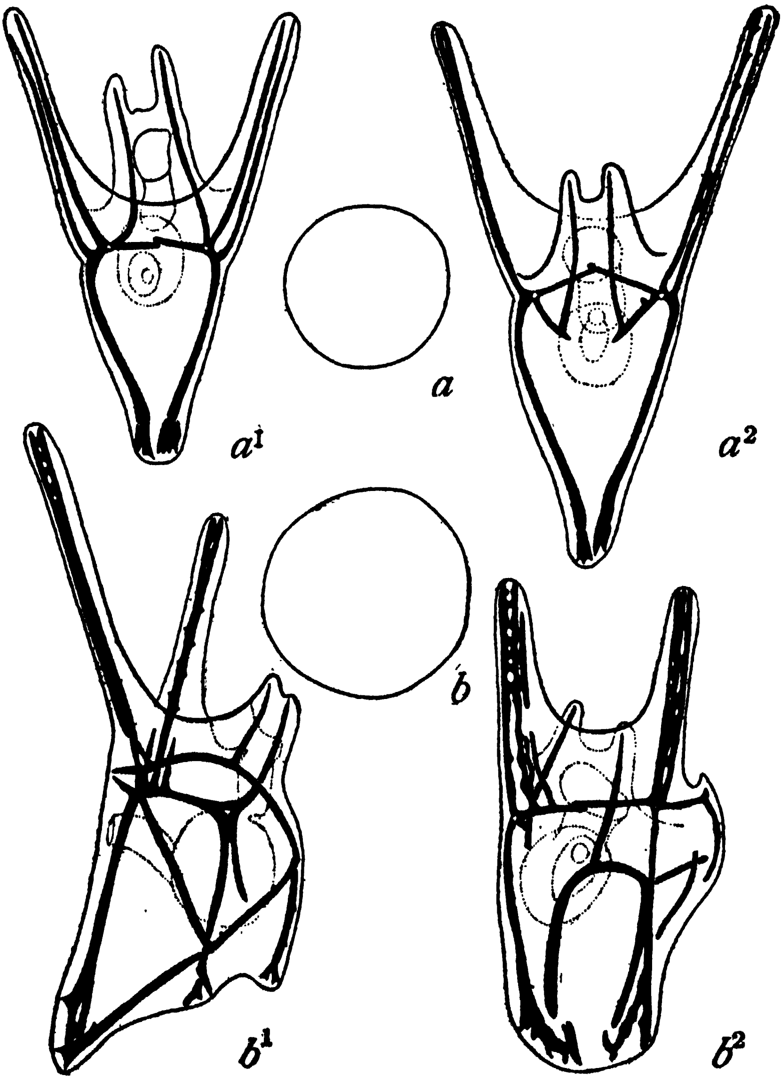


FIG. 2

tetraploid (fourfold) and represent four potential eggs fused together. On the other hand, it is possible that some of the differences are only fluctuations in size of a diploid nucleus. It will require chromosome counts to decide this question, and at present we have only those of Bierens de Haan, that, as far as they go, indicate a diploid condition. Herbst is inclined to interpret the more maternal characteristics of the hybrid giants as due to the larger amount of maternal chromatin in the nucleus. This means that the result depends on the greater influence of the larger num-

ber of the maternal chromosomes, and is in accord with genetic results in general.

Boveri ('13) obtained five giant plutei from giant eggs of Sphaerechinus fertilized by Strongylocentrotus sperm. These, he states, resemble the maternal type of pluteus more than does the hybrid from the normal sized egg. Boveri discusses the problem as to whether the maternal character of these giants is due to the greater quantity of the protoplasm of the egg or to the double-sized nucleus. By means of the following experiment he showed that the amount of the protoplasm does not in itself affect the character of the hybrid. Some normal eggs of Sphaerechinus were broken into fragments. The nucleated fragments were then fertilized by sperm of Strongylocentrotus. Other eggs, not shaken, were cross-fertilized, and then placed in Ca-free sea water. When the two-cell stage was reached, the blastomeres were separated. Both lots were allowed to develop into plutei. An equal number (20) of the same sized plutei of the two lots were compared, *i.e.*, those from the ½ blastomeres were compared with embryos of the same size from the fragments. Both were alike; *i.e.*, neither showed a greater tendency to be like the paternal type of pluteus than did the other. This experiment was devised in order to test whether the amount of protoplasm of the egg, as compared with the possible importation of protoplasm by the sperm, is the factor involved in the maternal character of the hybrid from giant eggs as contrasted with the hybrid from normal eggs. Now in the fragment the sperm must import the normal amount of its own cytoplasm (if it does import any cytoplasm at all), while in the ½ blastomere this postulated cytoplasm has been distributed as in the normal egg. The embryo from the fragment is no more paternal than the embryo from the blastomere. The question may be asked why was not this result equally well shown by a comparison between the hybrid from a normal egg with that from a fragment of the normal egg. The answer is that the small embryos from fragments often have a less well-developed skeleton, hence they might appear more like the paternal type which is also the simpler type in this particular case. This objection is met, however, by the experiment as planned and carried out by Boveri.

The same problem comes up again in connection with Herbst's results from cross-fertilized eggs of Sphaerechinus whose development had been already started by chemical means. These eggs (normal in size) if fertilized by sperm of Strongylocentrotus give rise to plutei that are more like the maternal type than like hybrids from normal eggs. It has been shown by Herbst ('06, '07) and by Kinderer ('14) that these treated eggs have doubled the number of their chromosomes before fertilization. There are twice as many

egg-chromosomes as sperm chromosomes with the result that the influence of the maternal chromosome is stronger than when the two kinds of chromosomes are equal in number. Since the protoplasm is the same in the two cases it is clear that the result is due to the chromosomes, although here a possibility is not excluded entirely, namely, that the initial stimulus given to the egg by the parthenogenetic agent is responsible for the more maternal character of the pluteus; or else as Boveri has suggested the sperm cytoplasm may have become injured, or affected by the changes that have taken place in the egg before the sperm entered, hence its less efficient participation in the characters of the hybrid.

Double-Sized Eggs of Ascaris

The eggs of the thread worm of the horse, *Ascaris megalocephala,* have furnished interesting cases of fusion. The eggs are said to unite in some cases before, in other cases, after fertilization. Occasionally, some of these double (Figs. 4, 5, 6) eggs appear to give rise to single giant worms. Sala ('93, '95), zur Strassen ('96, '98) and Kautzsch ('13) have described the process of fusion and its subsequent results, but their accounts differ in certain important points. For instance, there is some doubt as to the time at which the union takes place. Sala suggests that some of the unions are due to incomplete separation of the oogonia in their last divisions. Such eggs with two nuclei would, he thinks, behave like normal eggs. They would be expected to form four polar bodies, two from each nucleus, and be fertilized by one sperm. They would then contain a triple set of chromosomes. The development of such eggs was, however, not followed. In other cases double or triple eggs (Fig. 3) may be produced, according to Sala, by the action of

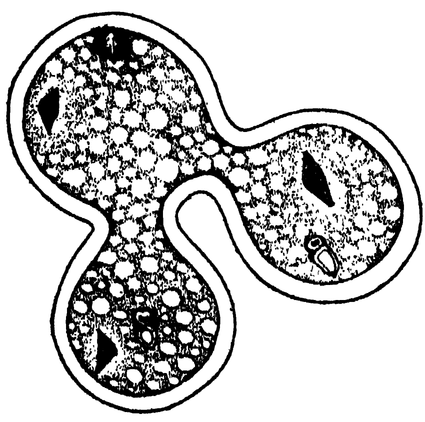


Fig. 3

cold on the eggs. The jelly formation is delayed, or, if formed, it remains soft and the eggs may stick together and even become united by bridges of protoplasm. Later, the fusion may go farther. Such unions he supposed to take place either before or just after fertilization. The number of sperms that enter the eggs is variable. The eggs later die without forming embryos.

Zur Strassen believes that the union takes place between separate eggs. He found that a low temperature might increase the number of unions, but was not the only cause of such unions. The union takes place usually between naked eggs, *i.e.*, before the jelly is formed. One sperm may enter. The polar bodies from each nucleus are extruded sometimes at opposite sides, and sometimes near together. Zur Strassen believes that eggs may also unite even after their membranes have developed. The membranes stick together, fuse, and a canal develops between the two. Through this canal the protoplasm from one egg passes and unites with the protoplasm of the other egg (Fig. 6, a). The two eggs are then supposed to flow together and unite into a single more or less spherical mass (Fig. 6, c).

Kautzsch states that a single interpretation will cover all the cases observed by Sala and by zur Strassen. He points out that if the fused eggs are arranged in the order of their stages of polar body formation, the youngest stages are always those without a membrane. In Fig. 4, a, the first two polar bodies are being given off from a double egg. One spermatozoon is present. A slightly later stage of another egg is shown in Fig. 4, b; both polar bodies are formed near together and two sperms are present. In still another egg, Fig. 4, c, the polar bodies have been given off by each nucleus, but at different poles. Only one sperm is present. In another egg, Fig. 5, a, all four polar bodies are near together in the constricted region; two sperms have entered. This egg is dumb-bell-shaped. In contrast to the last two cases the four polar bodies represented in Fig. 5, b, lie at the surface in one of the dumb-bell-shaped combinations, and the two sperm nuclei lie one

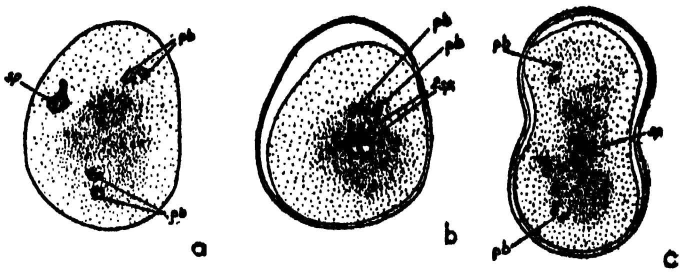


FIG. 4

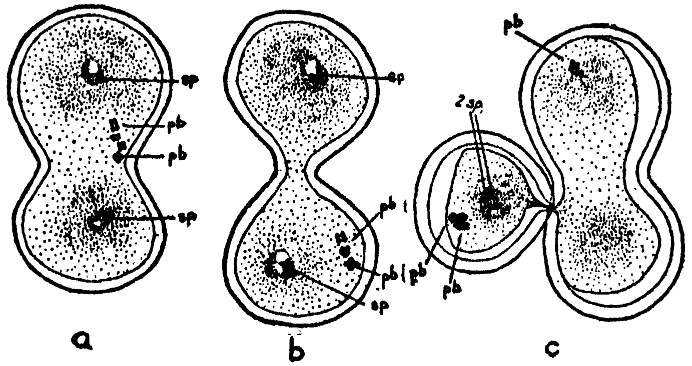


FIG. 5

in each of the rounded ends of the double egg. The union of three eggs is shown in Fig. 5, c. The polar bodies of one egg of the three lie in the dumb-bell-shaped (right hand) part, and the polar bodies of the other two eggs lie in the left hand portion that is now constricted off from the dumb-bell part. Two sperm are present in the smaller part. Kautzsch argues that in this case it is improbable that one nucleus could have passed through the narrow connection to form its polar body with the left hand egg, and that it is more probable that, after two of the fused eggs have given off together their polar bodies, a constriction appeared that forms the bridge between them. In other words, he thinks that in all these cases the eggs were at first more or less closely fused, and that after extrusion of the polar bodies and fertilization, the halves tend to round up again. This gives rise to the dumb-bell combinations seen in so many cases. Thus he reverses the order of events postulated by Sala and zur Strassen for many of the double eggs. In favor of Kautzsch's view are those cases where the polar bodies are given off near each other, for it does not seem probable that they could have been secondarily brought into this position by a union of the eggs after they had been extruded. Also in favor of his interpretation is the improbability that union could take place after the jelly and fertilization membranes had been formed. Both zur Strassen and Kautzsch agree that in later stages, after segmentation has taken place, the two eggs may sometimes come together to form a more nearly oval or spherical embryo, Fig. 6, b, c, f.

The segmentation of some of the double eggs that fused at an early stage has been followed by zur Strassen. The segmentation of many of the double eggs shows generally great irregularity arising from the presence in them of two separate egg-nuclei and one or two sperm-nuclei. When two sperm-nuclei are present, two spindles or a multipolar complex of spindles develops that leads to

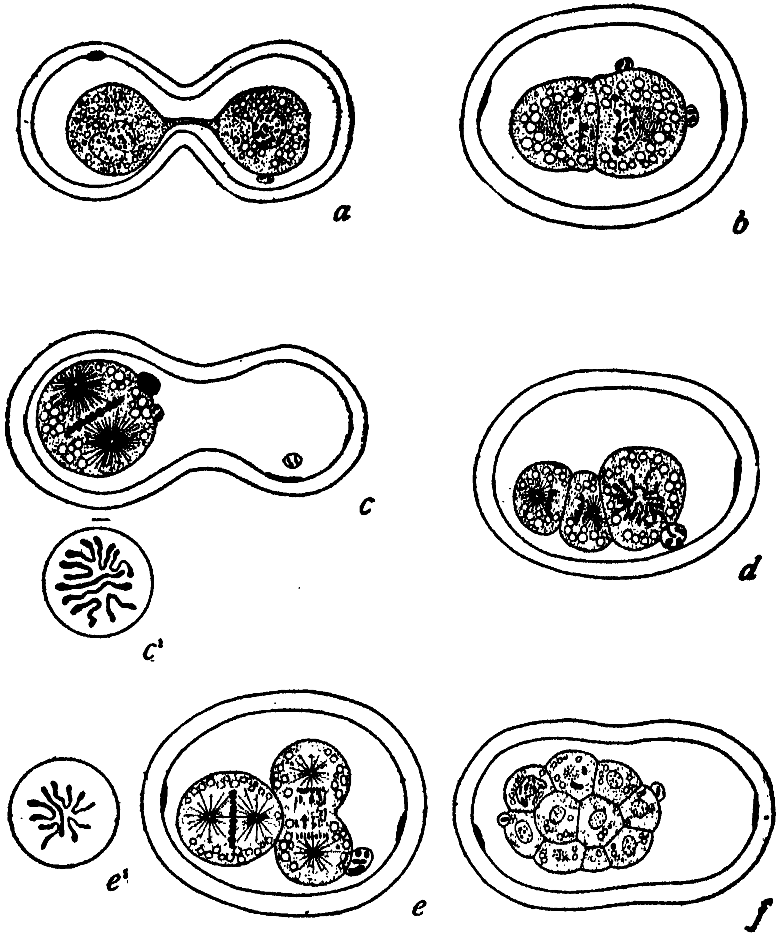


FIG. 6

irregularities in the distribution of the chromosomes as well as to irregular division of the cytoplasm. When one sperm nucleus is present, a regular spindle may develop, whose metaphase plate (Fig. 6, e^1) contains the six chromosomes derived from the three nuclei present. What percentage of such eggs develop as a single unit is not known, but since later (Fig. 6, f) giant eggs with normal cleavage pattern are sometimes found it is probable that on rare occasions the development proceeds in quite a normal way (Fig. 6, c, e, f). It is also possible that in other cases when two sperm have entered, a normal cleavage may take place provided a single spindle develops. The presence of 8 chromosomes in such an egg (Fig. 6, c, c^1 and d) is evidence that two sperm have entered. It follows that both triploid and tetraploid embryos may develop into giants. As stated above, zur Strassen records finding a giant embryo (Fig. 7,

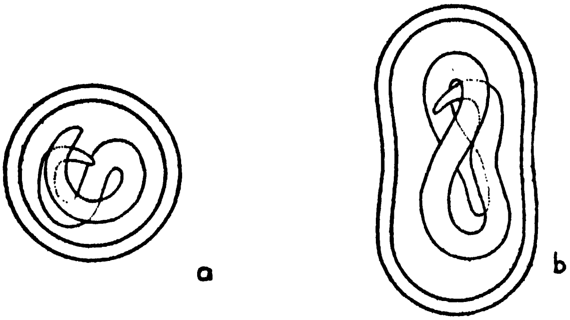


FIG. 7

b) within one egg-membrane, and the size of the double embryo as compared with the normal (7, a), as well as the size and shape of the membranes, leave no doubt as to their double origin. The results show that some of the unions at least are of such a kind that the protoplasm of two eggs and probably also the nuclei of the two eggs have united and produced a single embryo of double size.

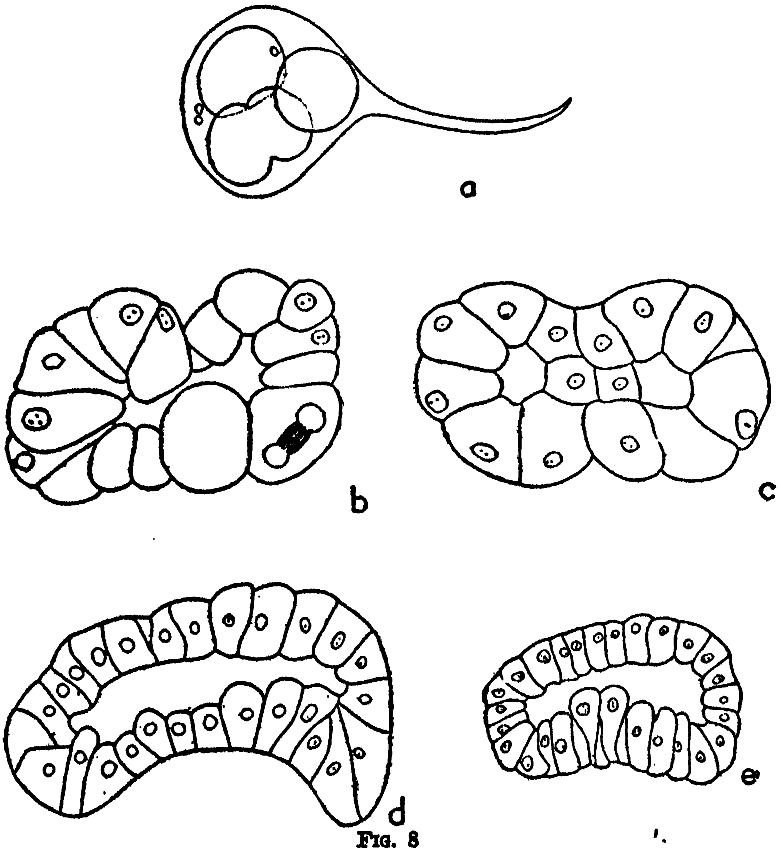


FIG. 8

Double Eggs of Nemerteans

Giant embryos of the nemertean, *Lineus ruber,* arising from the fusion of two eggs, have been described by Jozef Nusbaum and M. Oxner ('13). The eggs are laid in cocoons, two or more eggs in each. They may fuse before cleavage (Fig. 8, a), during cleavage or in the blastula stage (Fig. 8, c). The eggs that fuse before cleavage may contain two or more nuclei, but sometimes only one. When more than two eggs fuse, the cleavage is so irregular that embryos do not develop, but when only two eggs fuse (Fig. 8, b) gastrulation (Fig. 8, d) may take place and a giant embryo may be formed. Two fused eggs may have a common blastocoel and a single archenteric invagination. These appear to give rise, at times, to single giant embryos. When partial fusion takes place between two blastulae (Fig. 8, c) each may invaginate separately. The double-headed embryos that have been found (Fig. 9, a, b) may be produced in this way.

The development of whole embryos from parts of eggs, or from isolated blastomeres, or even from pieces of blastulae in another nemertêan (Cerebratulus) indicates that the blastomeres of these worms are little differentiated, or else have extensive powers of "regulation." Hence, the results of fusion of two eggs or embryos are entirely consistent with the known possibilities of these eggs.

Giant Embryos of Triton

The union of two eggs of Triton to form a single giant embryo has recently been brought about by Mangold ('20). The eggs were removed from the jelly as they were passing into the two-cell stage.

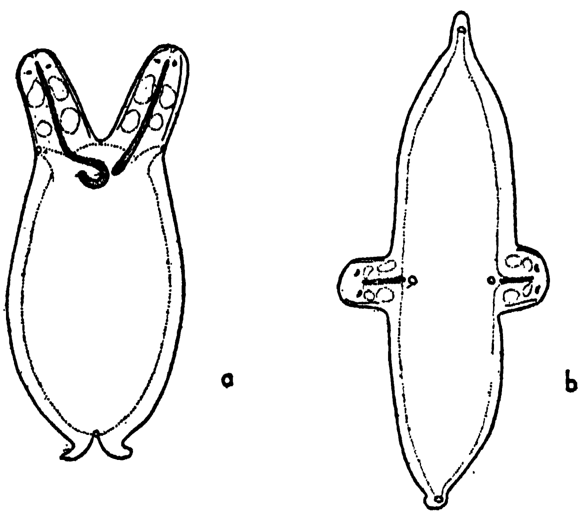


Fig. 9

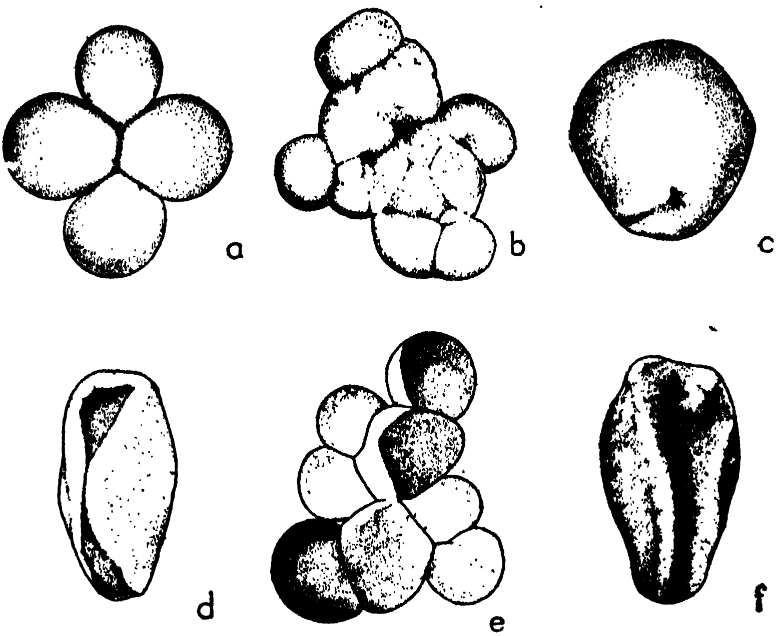


FIG. 10

In the absence of the membrane the egg flattens and the first two blastomeres at the height of the division period separate widely until they are nearly tangent to each other. One such egg is then lifted up and laid across another one in the same stage (Fig. 10, a). As soon as the four blastomeres begin to draw together they flatten against each other. This union becomes more and more intimate as the cleavages proceed (Fig. 10, b). Gastrulation takes place later (Fig. 10, c), and a single embryo may be formed (Fig. 10, d) or else two or even three embryos united together may result.

In order to understand the different possibilities involved when two eggs of Triton are brought together it is necessary to take into account the fact that the first cleavage plane is sometimes median (Fig. 11, a) and at other times frontal (*i.e.*, across the median

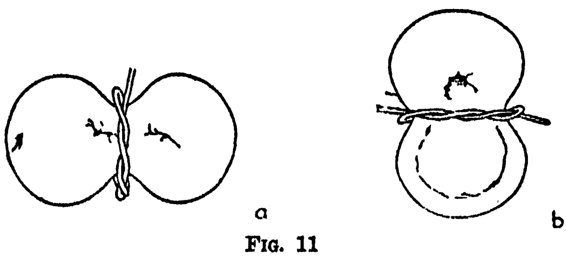


FIG. 11

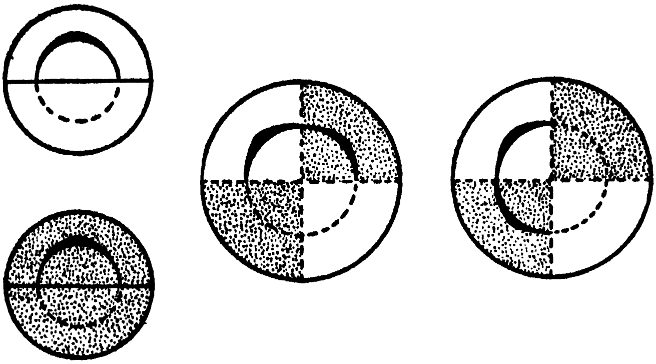


FIG. 12

plane, Fig. 11, b). By means of the following diagrams (Figs. 12, 13, 14) the possible relations of the fused eggs to each other are shown (one egg is stippled in each case). The first plane of cleavage is indicated by the straight continuous line, and the future position of the dorsal lip of the blastopore (by which the median plane is indicated) is represented by the black crescent. The two small circles to the left represent the kinds of embryos involved with respect to the first cleavage plane. The two larger circles to the right represent in each case the result of the combination of the former to produce a giant gastrula.

In Fig. 12 the first furrow in each embryo is frontal. When eggs of this sort, in the two-cell stage, are laid across each other the two possible relations of the future blastopore are represented by the two larger circles to the right. In each case the rim of the blastopore forms a continuous half circle of double size. Here the axes of the two united embryos coincide as far as possible.

In Fig. 13 the first furrow in each embryo is median. When two such eggs in the two-cell stage are laid across each other, the two possible relations are shown by the larger circles to the right. Here

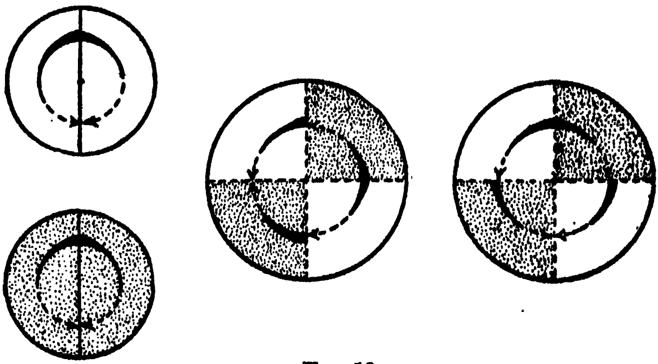


FIG. 13

there is one normal sized dorsal lip made up of halves of each embryo and two half dorsal lips in the other hemisphere. The axes of the two embryos are in the same direction, but there is only one whole dorsal lip formed by the juxtaposition of two half lips.

In Fig. 14 the first furrow in one embryo is frontal and in the other embryo median. When two such eggs in the two-cell stage are laid across each other, the two possible relations are indicated by the larger circles to the right. In the first of these a single dorsal lip is continuous at its edges with the two half lips of the other embryo. The axes of the two are nearly in the same direction. In the second, the single dorsal lip is isolated from the two half lips of the other embryo, and the axes of the two embryos are approximately reversed.

There is a very high mortality, but this is also true for single eggs that have been removed from the jelly membrane. Failure of the giants to develop is due, no doubt, in part to their exposure, but probably also in some cases to difficulties resulting from the enforced union of two eggs and the resulting maladjustment of their parts. In two cases, nevertheless, single, normal embryos of giant size were obtained. One of these came from two eggs of *Triton taeniatus* (Fig. 10, d) and the other (Fig. 10, e, f) from an egg of this species united to the egg of another species, *Triton alpestris*. It was not possible to determine the nature of the special kind of combination that gave these results, but it seems not improbable that they came from such a union as that shown in Fig. 12, or from the first union shown in Fig. 14.

Mangold also describes another monstrous embryo in which three anterior ends or heads were united into a single giant. Such an embryo is expected to arise from some of the other unions shown in the diagrams.

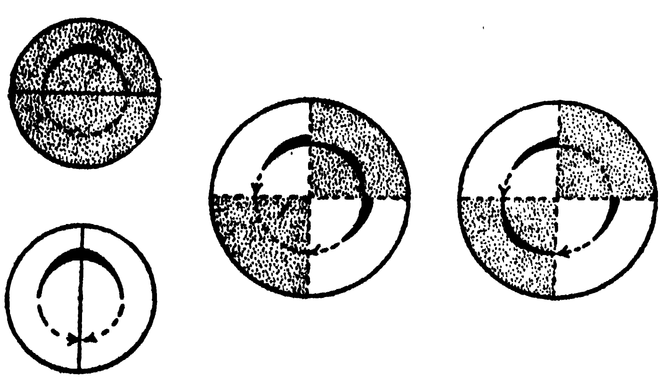


Fig. 14

These results, although somewhat meager, show, nevertheless, the possibility of forming a single embryo of Triton by the union of two eggs at the two-cell stage. They are, moreover, in accord with the results obtained from isolated blastomeres of these same eggs.[3] The outcome suggests that even although at the two-cell stage the future axes of the embryo are determined, yet an adjustment is possible if the general orientation is the same in both components. It need not be assumed that this power of adjustment is greater than that shown by the isolated ½ blastomere that have come from eggs segmenting in the median plane. The triple giant corresponds perhaps more nearly with the embryos that come from ½ blastomeres from eggs whose first division was the frontal plane.

Double Eggs that are Not Giants

To what extent in other animals two eggs may fuse to produce single embryos is not known, but there is evidence to show that embryos may arise that are not giants but which, nevertheless, owe their origin to the fusion of two eggs; and it is also quite certain that many monstrous forms that have double structures do not arise from fused eggs. Let us consider first the latter situation. There is no evidence, for instance, that two-headed fishes, or chicks or turtles come from fused eggs. It is true there is no evidence to show that they do not arise in this way, unless the normal size of the eggs furnishes such evidence. There is in fact one case where four blastodermic areas (Fig. 15) have been found (Wetzel '00) on the same egg of a snake (Tropidonotus), and this at least suggests an earlier four-nucleated condition, but such observations are rare compared with the frequency of double embryos in other vertebrates.

Several writers have suggested that double chicks may arise from the entrance of more than one sperm into the egg, but the

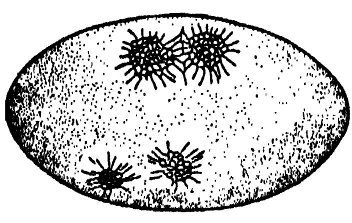


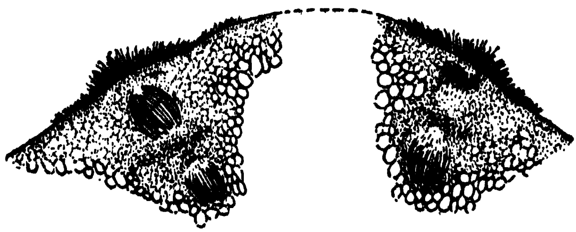
Fig. 15

[3] Mangold also produced single embryos of normal size by uniting halves of two eggs. The first two blastomeres were first separated from several eggs, then later when each of these was dividing, two of them were laid across each other. They united into a single embryo. The possibilities of combination are much the same as those described above for whole eggs, depending on the position of the first plane of division with respect to the axis of the embryo.

entrance of several sperms appears to be a normal occurrence in the hen's egg (Patterson '09). The extra sperms take no part in the later development. The not infrequent occurrence in the hen's egg of two yolks in one shell is due, as already mentioned, to the liberation of two eggs from the ovary at the same time, which, passing one behind the other down the oviduct, become enclosed in a common albumen and shell. They do not fuse and do not give rise to double monsters.[4] The multiple embryos of the armadillo have been shown to arise from a single egg (Patterson and Newman) by a sort of duplication or "budding" in a stage following cleavage. There are no grounds for assuming that the eggs have more than one nucleus, in fact, only one is figured in all the normal eggs that have been described.

The multiple embryos of certain parasitic wasps have also been traced (Bugnion ('91), Marchal ('04), Silvestri ('06), Patterson ('13, '15, '17, '18, '21)) to single eggs, each with a single nucleus. The mass of cells resulting from cleavage breaks up later into a chain of embryos.

There is one case in insects where eggs with two nuclei have been observed and where the changes that take place in them have been followed. Doncaster ('14) found in one strain of the moth Abraxas,


a

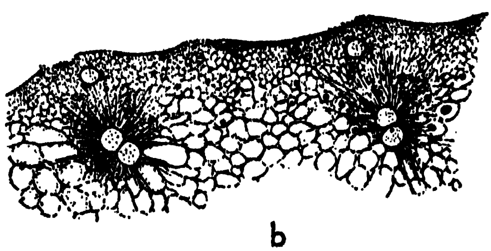

b

FIG. 16

[4] G. H. Parker ('06) has reviewed the literature on "Double hens' eggs." Raymond Pearl ('10) has described "A triple-yolked egg" and given references to other records of similar cases.

that certain individuals contained eggs with two nuclei (Fig. 16). Each nucleus forms its polar bodies (Fig. 16, a) and each reduced nucleus then apparently unites with a separate sperm-nucleus (Fig. 16, b). The observed entrance of more than one sperm into insect eggs, that has frequently been recorded, makes this latter occurrence not so unusual as might appear at first thought. These doubly nucleated eggs of Abraxas produce a single embryo normal in size, since the eggs themselves are not larger than normal ones. How these eggs arise is not known, but the conditions that prevail in the early germ track in insects, where a group of cells, derived from a single oogonial cell, becomes enclosed in a common follicle, would seem favorable to such a union. Furthermore, only one cell in each group usually becomes the egg while the rest remain as nurse cells. Although we do not know what conditions bring about the specialization between these apparently identical cells, it is customary to assume that the position in the group of one of the cells determines that it becomes the egg, hence it is easy to imagine that two cells failing to divide completely might reunite into one cell with two nuclei and become a double egg. Failure of such eggs to become giants may be explained by the restriction of the tube in which the egg is confined, or through which it passes during its growth stages. Possibly also in other cases the failure of such double eggs to grow to double size may be due to presence of only the normal number of nurse cells that supply a large part of the materials for growth.

Since it has been shown in moths that the female is heterozygous for a sex chromosome, it is evident that if two eggs should unite and each nucleus remain separate from the other, one nucleus after extrusion of the polar bodies might be left with the Z chromosome (the W chromosome being extruded) while the other nucleus might be left with its W chromosome (the Z being extruded). Since all the sperm are alike, *i.e.*, each carries a Z, it is obvious that a gynandromorph would arise, namely, an individual that is male on one side and female on the other. It is probable that some of the bilateral gynandromorphs that have been found in moths and butterflies may arise in this way. They are not so much double embryos, as two half embryos, one male and one female, united into one. There are still other ways in which bilateral gynandromorphs may arise and their occurrence does not necessarily mean that all gynandromorphs arise from binucleated eggs, but when a female is heterozygous for genetic factors other than those carried by the sex chromosomes, it may be possible to show by analysis that double nucleated eggs must have been the source of the mosaic individual that appears. There are, in fact, two cases of this kind described by Toyama in the silkworm moth both from the same brood. Here,

as shown by the analysis of the situation (Morgan '07, '13, '19), the two gynandromorphs must have come from a double nucleated egg. There are also a few other cases in moths where this explanation is probable. If there are no genetic factors present that make an analysis possible, the two half-individuals if of the same sex will pass for normal.

In the vinegar fly, *Drosophila melanogaster*, in which a large number of mutant races are known, and in which gynandromorphs are of frequent occurrence, there are occasional cases where the usual explanation of "elimination," in an embryonic division, of an X-chromosome from a dividing nucleus does not apply, but where the results are in full accord with the assumption of a binucleated egg (Morgan and Bridges '19, Morgan, Sturtevant and Bridges '23). At present, there is lacking the cytological evidence that is desirable before such cases can, with certainty, be referred to an egg with two nuclei, but the genetic evidence leaves little doubt as to the interpretation.

ORIGIN AND GROWTH OF THE WEATHER SERVICE OF THE UNITED STATES, AND CINCINNATI'S PART THEREIN

By Dr. W. J. HUMPHREYS

Meteorology in General

What is it moulds the life of man?
The weather.
What makes some black and others tan?
The weather.
What makes the Zulu live in trees,
And Congo natives dress in leaves
While others go in furs and freeze?
The weather.

This jingle has, perhaps, no claim to be recognized as poetry, but from beginning to end it is concentrated truth. The four great industries of primitive man, namely, hunting and herding, angling and agriculture, are each profoundly affected by the weather; and so, too, with scarcely an exception, are all our other and more modern industries, developed by the needs of a complex civilization. Hence, with the very dawn of his reason man of necessity became interested in the weather, nor, so long as he remains a rational being, can that interest lag.

Hence, most if not all primitive races have had their weather-wizards whose duty it was to bring rain in times of drought, or to stop the downpour and still the winds, as the needs of the people, or whims of a chief, might suggest. These miracles they sought to perform, and claimed to effect, through magic or by supplication or by some naïve mixture of the two. Nor, indeed, has civilized man yet wholly freed himself from even the crudest magic in respect to the weather, so desperate are we made and unreasoning by a withering drought, ruinous storm or devastating flood.

Next after weather-magic, in the development of meteorology, came the association of weather phases with previous occurrences; rain, for instance, with a halo the night before; or frost, for example, with bright moonlight; and so on through an interminable list, commonly expressed in the form of proverbs. Such proverbs, both those that now have the support of recorded observation and sound deduction, and also that much larger class that came from mere fancy, were among the earliest sayings to be conserved in manuscript for the benefit of future generations. They have come

to us in the Bible, in the Vedas and on cuneiform tablets. Many of them were compiled by Hesiod, we do not know exactly when, but not far from the time of Tutankhamen's youth, some 3,000 years ago. In the third century before Christ the Greek poet Aratus compiled all the weather lore of this kind known to him in his famous *Prognostica*. And the end is not yet, for this good work still goes on.

Very early, too, our knowledge of heat and cold, rain and shine, and other important weather phenomena, began forming into a more or less definite science, in the sense of being classified and explained. No one knows when nor by whom this scientific phase of meteorology was begun, but we do know that by the time of the fourth century before Christ it had grown to such magnitude that as assembled by Aristotle it made quite a treatise. We also know that for two thousand years this treatise by Aristotle was the most important of all works on meteorology, and that because of its great authority it eventually became rather a hindrance than an aid to an understanding of weather phenomena. Its logic is, of course, inductive, by which cause and effect are inferred according to association and order of occurrence. But induction is no longer sufficient in any of the physical sciences, however statistically supported the conclusions may be. We now also demand abundant deduction, or the rational prediction of effects from assumed causes. Hence, Aristotle's treatise marked only a phase, though an extremely important and long-enduring one, in the science of meteorology.

Obviously, no natural science, in the sense of classified phenomena and their logical explanation, can grow, or even come into existence without both a mass of observations and a body of logical reasoning thereon. Furthermore, in the realm of the physical sciences, of which meteorology is a member, the more accurately quantitative these observations are the more rigid and reliable the reasoning can be. Therefore, the next great advance after the work of Aristotle was the invention and use of quantitative weather instruments, especially the thermometer, generally attributed to Galileo, who is believed to have constructed the first closed instrument for observing differences in temperature in 1612, and the barometer devised and constructed by Torricelli in 1643. Crude rain gauges and wind vanes had been in use from time to time since about a hundred years before the beginning of the Christian era, but it was not until after the invention of the thermometer and the barometer, that is, not until the middle of the seventeenth century, that it was even possible to obtain numerically comparative values of either temperature or pressure, the basic factors of meteorology. Of course none knew better than even the savage when the air was

comfortably warm, nor realized more fully that at times it became bitterly cold. But such terms as hot, warm, mild, cool and cold covered the whole thermometric scale of even such great rulers as Charlemagne and William the Conqueror; such literary celebrities as Dante and Chaucer; such explorers as Columbus and Hudson; or such penetrating scientists as Leonardo da Vinci and Roger Bacon. Nor had any of them the slightest idea that the pressure of the atmosphere varied from time to time and place to place. They could not tell what made the winds to blow nor why storms came and went.

With the invention of the thermometer, however, the barometer, and certain other instruments, it immediately became possible to collect quantitative values of every important weather element, both at stated intervals by eye readings, and continuously by means of automatic recording devices. And such values were promptly collected at many places. Thus, as early as 1664, or only a few years after the invention of the barometer, Dr. Beal discovered the double diurnal variation of the atmospheric pressure, an interesting, though generally inconspicuous, phenomenon that even yet commands the attention of observer and philosopher alike. Since that time—about the middle of the seventeenth century—we have collected meteorological data in increasing abundance and with ever closer attention to details from many parts of the world. The first organized body of observers, supplied with like instruments and making similar records, was formed in 1654 by the Grand Duke Ferdinand II of Tuscany. These were located in Italy and adjacent countries, and continued their systematic observations until about 1667. Few, however, of their records have been preserved. During the next hundred years several similar undertakings were begun in England, France and Germany. Then, in 1780, the Meteorological Society of the Palatinate was founded at Mannheim under the auspices of the Elector Karl Theodor. Standard instruments were distributed to observers scattered as follows: Fourteen in Germany, two in Austro-Hungary, two in Switzerland, four in Italy, three in France, four in Belgium and Holland, three in Russia, four in Scandinavia, one in Greenland and two in North America—at Bradford and Cambridge, Massachusetts. The detailed data obtained by these widely scattered observers down to 1792 were published in twelve large volumes.

About the middle of the nineteenth century, that is, shortly after the invention of the electric telegraph, organized meteorological services began to be established, for the purpose both of systematically recording the principal weather elements and of warning those interested of an approaching storm. The first of these ser-

vices was authorized by France in 1855 and put in operation the following year. They now are maintained by all the more progressive governments the world over. Furthermore, as the success of wireless transmission grew meteorological reports to and from vessels at sea correspondingly advanced until to-day the ocean is all but as well manned and served meteorologically as the land.

Finally, near the first of the twentieth century systematic explorations and studies of the free air up to the greatest attainable heights began to be made, and are now being made in greater volume than ever before.

Whenever, now, for any reason whatever, we wish to know what the climate of any particular country, town or district is, we have only to look up its weather records—that is, if it has such records, and it always has if it belongs to a progressive part of the world. We use these accurate records of the weather of yesterday, last month or last year, in settling many a legal dispute and in answering a thousand other questions. The telegraphed reports of to-day's weather have equally varied applications. They are used by the merchant in deciding, for instance, whether he shall order a particular shipment to proceed at once or to delay for further instructions; by the citrus grower, for example, to know when the other fellow's orchard is being frosted, say, for that will immediately boost the value of his own crop; by every stock exchange; and many others for a great variety of reasons. They are also used by the forecaster in deciding what the weather is likely, in every essential, to be to-morrow and the day after—a foreknowledge of inestimable worth. Furthermore, this vast amount of quantitative data, from so many parts of the world, land, ocean and skies, furnishes both the occasion for and the proper tests of all those hypotheses and theories that together constitute rational meteorology. With so many reliable quantitative data available we are no longer confined to inductive reasoning about causes and effects in respect to weather phenomena, but can also employ deductive reasoning, by which previously unsuspected relations and phenomena are revealed. In this way meteorology has truly become a natural science—a subject concerning which our knowledge progresses by deductive reasoning and observational or experimental test.

Such, in general, has been the course of meteorology through the ages. It will be interesting next to consider how America's Weather Service, in particular, originated and into what it has grown.

Applied Meteorology in the United States

The earliest records of weather kept in the United States, like the early records in Europe and elsewhere, were owing to individual

stimulus and enterprise. The burden they imposed on the observer was voluntarily assumed and without financial compensation. Even the recognition, or good repute—a thing every self-respecting man strives to merit—that one got from even a decennium of daily reports was mostly posthumous. We do not know in all cases just why these records were begun, but we do know that they served two useful purposes: they told with an exactness that otherwise could not have been had what the climate was of the place in question; and they furnished facts of great help for the correct settlement of questions in litigation.

The first regular record of the weather anywhere on the American continent was kept during 1644–1645 by the Rev. John Campanus at the Swedes' Fort, near Wilmington, Delaware. But Campanus soon returned to Sweden, and after that it was a long while before any one else in this country had both the desire and the patience to keep such a journal. At any rate, the next weather record in America appears to be that for 1729–1730, kept at Boston by the Hon. Paul Dudley, Chief Justice of Massachusetts. A little later, 1738–1750, Dr. John Lining kept at Charleston, South Carolina, a detailed registry of four weather elements, namely, temperature, using a Fahrenheit thermometer made and standardized in England, pressure, humidity and precipitation.

In 1739, Benjamin Franklin, during his voyage homeward from England, took full and systematic notes of the weather and of the temperature of the ocean, using a Fahrenheit thermometer.

From 1742 to 1778 Professor John Winthrop, of Harvard College, as it was then called, kept a regular set of meteorological records.

In 1743, Benjamin Franklin reached the important conclusion that a particular storm in September of that year had travelled eastward across the country. This conclusion was based on reports from many postmasters, and from the fact that an eclipse of the moon was not visible at Philadelphia, owing to the presence there of this storm, while at Boston the eclipse was seen and was over before the storm began. This was the first determination, in America at least, of the direction of travel of a storm as a whole. The rain might come with the winds from the east, but the storm itself moved towards the east.

From this time on weather records in greater or less detail have been kept almost continuously by private individuals and institutions at one or more places in the United States, as also, of course, in many other countries, including our good neighbors, Canada and Mexico. Many excellent records of this kind are still being made, and are useful, even though practically all progressive governments

are now, and for round half a century have been, keeping meteorological records on an extensive and elaborate scale.

From 1772 to 1777 Thomas Jefferson, at Monticello, Virginia, and James Madison, at Williamsburg, Virginia, made simultaneous observations of temperature, pressure, wind direction and other weather elements. These observations have the distinction of being the first made in America in accordance with the agreement that they should be simultaneous, a condition that makes them far more valuable than they otherwise would be.

The credit for taking the first official observations of the weather in this country belongs to the Army Medical Department. An order, dated May 2, 1814, makes it a duty of hospital surgeons to keep a diary of the weather; and one such journal, specifically recognizing this order, and kept at Cambridge, Massachusetts, is dated July, 1816. This order appears to have been heartily endorsed by the first Surgeon General of the Army, General Joseph Lovell, appointed in 1818. In urging the approval of the order that such diaries of the weather be kept he says: "Every physician who makes a science of his profession or arrives at eminence in it will keep a journal of this nature, as the influence of weather and climate upon diseases, especially epidemics, is perfectly well known. From the circumstances of the soldier, their effects upon diseases of the army are peculiarly interesting, as by proper management they may in a great measure be obviated. To this end every surgeon should be furnished with a good thermometer, and, in addition to a diary of the weather, should note everything relative to the topography of his station, the climate, complaints prevalent in the vicinity, etc., that may tend to discover the causes of diseases, to the promotion of health, and the improvement of medical science."

At about this same time, specifically, in 1817, organized meteorological work was begun by the government under the direction of Josiah Meigs, Commissioner-General of the Land Office, who established a system of tri-daily observations at the various land offices.

The first volume of the meteorological observations by the Army Medical Department, covering the years 1822–1825, inclusive, was published in 1826. One purpose of this publication was to stimulate the study of the then mooted question whether there is any progressive change in the climate of any portion of the country, and, if there is, how it is related to settlement and cultivation, a problem that has not yet been solved in all its details.

The second volume of these observations covered the years 1826–1830. One of the most important climatic generalizations thus obtained was the fact that, other things being equal, near large bodies of water, whether ocean, gulf or lake, the climate is more equable than it is far inland.

By this time important generalizations in meteorology also were being made, both in this country and abroad; for example, that the air cools by expansion incident to convection, announced in 1830 by James P. Espy; and that the winds blow around the centers of low-pressure storms, as explained by W. C. Redfield in 1831. These generalizations, and the scores of others that have been published during the century, nearly, since they appeared, belong to the theoretical side of meteorology, and therefore are extremely fascinating. In fact, without theory in meteorology, that is, the logical assignment of cause and effect, the growth of every weather service would be slow and uncertain. Nevertheless, weather service, not weather theory, is our present theme. Hence neither the above nor any other such laws will be further considered.

Obviously, there can be no efficient and sustained public service without public support. Hence, an important event in the origin and growth of the weather service of this country was the grant, the first of its kind in America, of $4,000 made in 1838, by the legislature of Pennsylvania to the Franklin Institute for the collection of weather information. No doubt the stimulus that secured this grant was the fine meteorological work and buoyant enthusiasm of Espy, then connected with the Franklin Institute.

The red letter year, perhaps, in the history of applied meteorology, was 1845. In that year, on the first of April, a commercial telegraph line was opened to public use. After that date any one could, and many did, see the possibility of forecasting the weather by the obvious and simple process of telegraphing ahead what was coming. However, the first person actually to begin work of this kind was Joseph Henry, then secretary of the Smithsonian Institution. In his "Program of Organization," submitted on the 8th of December, 1847, he says:

> Of late years, in our country, more additions have been made to meteorology than to any other branch of physical science. Several important generalizations have been arrived at, and definite theories proposed, which now enable us to direct our attention, with scientific precision, to such points of observation as can not fail to reward us with new and interesting results. It is proposed to organize a system of observation which shall extend as far as possible over the North American continent. The present time appears to be peculiarly auspicious for commencing an enterprise of the proposed kind. The citizens of the United States are now scattered over every part of the southern and western portions of North America, and the extended lines of the telegraph will furnish a ready means of warning the more northern and eastern observers to be on the watch for the first appearance of an advancing storm.

This recommendation was promptly adopted by the Board of Regents and money appropriated for getting it started.

By the end of 1849, 150 people, widely scattered, were taking weather observations and reporting them to the Smithsonian Insti-

tution. In this year also the telegraph lines began giving to the institution, and without charge, information in regard to the existing weather at various places.

The next obvious step was the construction of a map showing the current weather conditions over the country, and this step the institution took in 1850—only five years after the opening of the first of all telegraph lines! This map was not manifolded and distributed to the public but the single copy was mounted where it could easily be seen, and corresponding signals were displayed on the high tower of the institution. Thus were begun the first, so far as we know, systematic and organized meteorological reports by telegraph, and the construction of the first maps, for public information, showing the existing state of the weather over a large territory.

During the same time that Joseph Henry and his colleagues, Espy, Coffin and others, were doing their fine meteorological work for the land, Lieutenant Matthew Fontaine Maury, then (1844–1861) superintendent of the U. S. Naval Depot and Observatory, with the friendly cooperation of ship captains, was assiduously collecting from log books that great fund of information concerning the weather of the seas that gave us our first reliable knowledge of ocean climates. Thus was marine meteorology firmly established, a branch of weather service that to this day has grown in magnitude and increased in importance.

Maury's connection with the Naval Observatory and his activity in the collection of marine data terminated with the beginning of the Civil War. At the same time the meteorological work of the Smithsonian Institution was greatly reduced.

The center of meteorological interest and activity in this country, in respect to weather forecasting, now shifted from the capital of the nation to the Queen City of the West. On February 1, 1868, Professor Cleveland Abbe became the director of the Cincinnati Observatory, and in his inaugural report, June 30, 1868, to the Board of Control, he said:

> If the director be sustained in the general endeavor to make the observatory useful, he would propose to extend the field of activity of the observatory so as to embrace, on the one hand, scientific astronomy, meteorology and magnetism, and, on the other, the application of these sciences to geography and geodesy, to storm predictions, and to the wants of the citizen and the land surveyor.

During his directorship of the Cincinnati Observatory, Professor Abbe's active interests turned more and more to meteorology, and especially to that application of it by which warnings may be given of approaching storms. On July 29, 1868, he sent a letter to Mr. John A. Gano, president of the Cincinnati Chamber of Commerce, emphasizing the practical importance of storm warnings, and

setting out in detail a plan by which, with the aid of the telegraph and the press, he could prepare and issue such warnings.

After much consideration of this proposition, Mr. Gano requested Professor Abbe to send him a second letter that could be presented to the Cincinnati Chamber of Commerce. The requested letter was sent, also a sketch showing some of the stations from which reports would be desired, and a sample dispatch.

The happy results of this appeal are told in the following quotation from Professor Abbe's report of June 18, 1870, to the Board of Control of the Cincinnati Observatory:

> The importance of anticipating the changes in the weather, especially storms or droughts, was alluded to in my report of June, 1868. This subject having been brought by myself to the attention of the Chamber of Commerce of this city, that body, in June last, authorized me to organize a system of daily weather reports and storm predictions. Experienced observers at distant points offered their gratuitous cooperation. The Western Union Telegraph Company offered the use of their line at a nominal price. The bulletin began to be issued September 1, in manuscript form, for the special use of the Chamber of Commerce, and began to be printed a week later as an independent publication.
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> This bulletin was supported for three months, as at first agreed on, by the Chamber of Commerce; its conduct then passed entirely into the hands of the observatory, and has thus continued until the past month. The independent publication of the bulletin was, however, discontinued, and it has, since December 1, only appeared in the morning papers. The daily compilation of this bulletin for the newspapers was undertaken two weeks ago by the Cincinnati office of the Western Union Telegraph Company, and will so continue, thus relieving the observatory of all further responsibility.
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> In February the manager of the Cincinnati office undertook the publication of a daily weather chart, and the favor that this has met with insures its continuation in the future. The Daily Weather Bulletin and Chart are, therefore, now supported solely by the Western Union Telegraph Company, and must be considered as a very important contribution to meteorology. It would have been highly to the credit of the observatory could these publications have been maintained in its own name; but this was impossible, owing to the want of funds and assistants.

The Weather Bulletins for September, October and November, 1869, were prepared by Professor Abbe, copied on manifold paper by clerks in the Western Union Office and delivered to patrons by the messengers. These copies were known by the descriptive term "greasers."

Professor Abbe's enthusiasm over his experiments in forecasting the weather may be inferred from a letter to his father, in which he said: "I have started that which the country will not willingly let die." And his estimate was correct. The earlier meteorological work of Joseph Henry, Espy, Redfield and others in this country; the success of certain already established weather services of Europe; and Professor Abbe's demonstration that valuable forecasts, based on telegraphic reports of the weather, could be made

also in this country, left no room for doubt. The time thus had become so ripe for a National Weather Service that less than six months after the first weather bulletin of the Cincinnati Observatory was issued the federal government, through a Congressional resolution signed by the president February 9, 1870, authorized the creation of a Weather Service, and placed it under the direction of the Signal Service of the Army.

The immediate chain of events that led to this wise action on the part of Congress, an action that Maury and others had previously advocated, was as follows: Earnestly anxious to secure storm warnings for the benefit of commerce on the Great Lakes, Professor I. A. Lapham, of Milwaukee, a close student of meteorology, drew up, in 1869, a petition for support addressed to the Chicago Academy of Sciences. This petition was presented for signature to the Honorable H. E. Paine, who, instead of signing it, as at first requested, fortunately took a much broader view of the subject and insisted that the petition should go to Congress, and the weather predictions be made for the whole country and not for any small section thereof. After making the necessary changes in the original petition, and securing for it the support of several chambers of commerce and the National Board of Trade, Mr. Paine took it in charge and quickly secured its adoption by a joint resolution enacted on February 4, 1870, which, as stated above, was signed by the president on February 9, 1870.

The chief position in this newly established service, next to that of the commanding army officer, was first offered to Professor Lapham, partly, no doubt, in recognition of his invaluable services in urging the importance of storm warnings, but also because of his knowledge of meteorology and for his obvious fitness for the position. Private considerations, however, prevented Professor Lapham from accepting this offer. Professor Abbe, widely and most favorably known because of his weather forecasts at Cincinnati, was then urged to accept this responsible position and finally prevailed upon to do so. His official connection with our Weather Bureau began on January 3, 1871, and terminated, owing to ill health, on August 3, 1916, after 45 years of fruitful labor for the development of meteorology and its adaption to human needs.

The work begun by Abbe in Cincinnati on small means, but with large vision, on being adopted and supported by the national government, as was both proper and necessary, has grown amazingly; and yet, as that vision clearly discerned, the demands of the public for meteorological service have always far exceeded the capacity of personnel and equipment to supply.

Present Activities of the U. S. Weather Bureau

The present activities of the Weather Bureau, in addition to many special investigations, and all the various duties incident to the instrumental equipment and proper maintenance of its numerous stations, may be classified roughly as follows: Observing and reporting, by telegraph and by mail; forecasting and disseminating the forecasts; assembling data for climatological needs; gathering and coordinating the weather records of ships for the development of marine meteorology; collecting and studying information bearing on the relation of weather to crops; getting and analyzing information concerning the temperature and other conditions of the upper air; reporting and forecasting river stages; measuring and studying solar radiation; measuring the kind and amount of dust in the air; and many others, generally either of smaller magnitude or not so exclusively of meteorological importance. It is impracticable with anything short of a volume, or, perhaps, volumes, to elucidate all the multifarious present-day work of the Weather Bureau. Perhaps, though, some notion of its magnitude may be gotten from the fact that in the interest of forecasting the bureau receives detailed weather reports daily, in most cases twice daily, from approximately the following numbers of stations in various parts of the world: The Far East, 12; Alaska, 12; Mexico, 20; Canada, 35; Europe, 25; West Indies, 30; the oceans (from ships), 100; United States, 200. In addition to all these, reports of the state of the upper air are received daily from six kite stations, and 40 pilot balloon stations, all in the United States.

For the detailed studies of climatology, there are used, in addition to all the above reports from the United States, similar data, sent in by mail, from about 5,000 cooperative stations, that is, stations officially equipped but tended without further cost by faithful enthusiasts—amateurs, working because the spirit of progress is in them, and deserving earnest thanks and unstinted praise.

The River and Flood Service alone gets readings of river stages from 500 different places, and rainfall from 500.

The division of Agricultural Meteorology is supplied with daily telegraphic reports from 400 stations, and written reports from 4,000.

Clearly, then (and this list is not complete), the meteorological organization of the United States has reached enormous proportions, though still far short of the development that would be necessary adequately to meet all the needs it alone could properly serve.

And what does all this contribution to science and thousand-sided aid to humanity cost the public? This practical, albeit sordid and selfish, question has a pleasing, a softly soothing answer—less than two cents per capita per year.

DEVELOPMENT OF TRANSPORTATION BY AIR[1]

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THE story of civilization is a story of constantly increasing speed and comfort of transport. Improving ease of communication has always brought in its train the possibility of preserving unity of feeling and of creating a national sentiment over larger areas than heretofore. It has contributed alike, insofar as it has appeared in any particular nation, to national safety and to the spread of national commerce. The direct economic gain from increased speed always has been, and always will be, great and unmistakable.

History offers no single instance of the long-continued neglect of a means of travel offering a great increase in speed combined with moderate economy and a reasonable degree of safety and comfort. There are, however, repeated examples of the virtual abandonment of one type of transporation in favor of another a little less comfortable, more dangerous, more costly, or all three combined, possessing only the cardinal advantage of speed. That being the case, it is not at all surprising that the airplane and airship have come into extended use for the transport of passengers, mails and goods, but it is very much to be wondered at that the United States, which has depended more than any other nation in the world upon good transportation for its economic development, should have lagged behind almost all the nations of Europe in putting aircraft to work under the auspices of private corporations, and that this country, which has firmly resisted government ownership and operation in most fields, should have been the only one in the world to depend on direct government operation of aircraft for a commercial purpose.

The one great advantage of aircraft for transport is, of course, their speed, which is far in excess of that of any surface vehicle, although the rates of travel realizable with economy are still much below those reached by racing airplanes carrying only a single pilot. A hundred miles an hour is the highest speed that can be considered as commercially practicable for the airplane at the present time, and it is better to operate at eighty to ninety where the nature of the traffic permits the slight corresponding increase

[1] Read before the American Association for the Advancement of Science—Section of Social and Economic Sciences—December 31, 1923.

of time for a journey. The airship, which will compete principally with shipping, is capable of sustained travel over distances up to 5,000 miles at about a mile a minute. There is little prospect that these speeds will be much increased, and the desirability of increasing them is open to doubt. It seems better to take aircraft as they now exist and to concentrate attention on so developing the machines and their auxiliary equipment that they will be capable of flying in all weathers and both by day and by night, with substantially perfect reliability and fair economy, rather than to seek for the production of a special form of winged projectile dependent for its operation on reasonably favorable conditions. Even the present-day commercial airplane can cut more than 50 per cent. from the train time on any long trip, and the airship will reduce the time required by the fastest ocean liner by from three fifths to three quarters on journeys over the sea.

There are, of course, some routes on which geographical conditions are peculiarly favorable to the use of the airplane, which passes over land and water, mountain and desert and forest, with indifference. The most notable example is the passage from London to the Continent, on which the traveler by air both saves a great deal of time and avoids the necessity of transshipping himself and his baggage at each shore of the Channel, to say nothing of escaping the crossing of that frequently very unpleasant body of water. Not unnaturally, it was between London and Paris that the first regular air line ran, and operation on that route has been continuous for more than four years now. The total number of passengers that have crossed the Channel by air since August 26, 1919, is more than 40,000, probably at least three times as many as have ridden on all the other air lines of the world combined in the same space of time. It is of interest to note, in view of the seeming reluctance of the American people to develop the commercial use of the airplane, that about one half of the total traffic, during the time for which statistics of nationality are available, has been made up of American tourists and business men. There has been a gradual increase in the amount of passenger business done on this particular route, and the number of passengers during a single month has run to over 2,600. The traffic has been highly seasonal, partly because of the tourist business in summer and partly because the prevalence of fogs and high winds in winter has interfered with the regularity and dependability of the service.

There are a score of other lines in Europe, most of them operating over distances much greater than that between London and Paris and most of them international in scope, for the most characteristic development of the last two years has been the suppression

of the short lines which connected two cities but had no direct share in any transportation system of continental extent, such routes having been served in some cases by two or three companies. They have been replaced by the longer routes for reasons partly economic, partly political. The saving of time by the use of the airplane becomes progressively more impressive and the usefulness of air transport to the business man becomes more and more apparent, as the length of route increases, for there is always a certain fixed time loss at the terminals, flying fields still being far from the cities which they serve in most instances. The time from New York to Boston by air, for example, including the time taken in traveling from New York to the flying field at Mineola and from the Boston airport to the center of the city, would be about three hours, a saving of only 40 per cent. over the performance of the fastest trains. From New York to Chicago, on the other hand, the total elapsed time would be about nine hours, which cuts well over half from the time of the limited train service. European airports are generally even farther out of the city than are American ones, and the use of long routes is correspondingly more important. Delays at international boundaries, too, make it possible for the airplane to show a greater relative advantage over the railroad in Europe than in this country. It is even now possible to fly from Vienna to Paris in ten hours, the best time by train being about 30, and to reduce the four days required by the Orient Express for the run from Strasbourg to Constantinople to 30 hours by airplane.

The political motive for the development of air routes is twofold. In the first place, the control of an important part of the transportation of one nation by the investors of another, working in close accord with their own government and receiving more or less direct support from it, is at once a useful, economic weapon and a means of extending national prestige and influence abroad. That its value is generally recognized by the governments of Europe has been proven by the intensity of the competition for the control of air transport in South Central Europe and in Russia, a competition to which France and Germany have been the principal parties. Second, rapid and efficient communication is an indispensable tool in the government of an empire, especially if any attempt is to be made to establish a federal system, and there is, therefore, strong incentive for the maintenance of air lines connecting the mother country with its dominions and colonies. Empires of great geographical extent arose in the distant past, but they always were purely military in nature, a single compact country sending forth armies to enslave the world. Such was Macedonia, such was Rome. The size of a self-governing unit has been limited by transportation,

and it has gradually grown from the city-state of ancient Greece and of medieval Italy, through the feudal barony offering but the most shadowy allegiance to a king, through the nation-state most characteristic of the last century, to the federal empire of world-wide extent, of which the British Commonwealth of Nations furnishes the most notable example to-day. The existing British Empire, with its present form of government and its periodic Imperial Conferences, would have been as unthinkable before the invention of the steamship as would the existing United States of America before the building of the railroads. Even to-day, the distance over which the largest empires spread is a source of strain, and aircraft, reducing as they do the time in transit of mail and passengers going home from the dominions, are eagerly welcomed by statesmen. Even where colonies, rather than self-governing dominions, are in question the airplane and airship offer an advantage in that it is easier to get the kind of man wanted for colonial service if he can keep in close touch with home affairs and spend a fair part of each annual vacation at home than it is if he must immure himself for a term of years far from home and friends and what he has learned to consider the essentials of civilization. It is such considerations as these that have led the French to run air lines out to Morocco and along the African coast from Tunis to Dakar with hardly a break, and that have led the British to point their endeavors always in the general direction of India, Australia, Egypt or South Africa. It is no mere coincidence that the three most notable long-distance cross-country flights ever made by British pilots established direct connection between the British Isles and Newfoundland, the British Isles and Cape Town, the British Isles and Port Darwin, in the Northern Territory. The latest issue of the French aerial pathfinder lists seven lines being operated under French control, and not one is confined within the boundaries of continental France. Regular schedules have been maintained during the past summer on nine routes exploited by German capital, and only one of the nine lies entirely in Germany, the others passing into Switzerland, Holland, Russia and all the Scandinavian and Baltic states. It is now possible to travel by air along a substantially direct line between almost any two of the European capitals and the whole distance of 3,000 miles from Casablanca to Moscow, with the exception of the 400-mile stretch between Toulouse and Paris, can be covered in an airplane flying on a regular route with at least tri-weekly service.

While this feverish activity in starting new companies and penetrating new countries has gone on in Europe, American development has proceeded on somewhat different lines. With no political incentive for the granting of direct government support, the use

of aircraft for passenger transport has proceeded comparatively slowly. There are several lines operating in the South during the resort season each winter, especially one between Key West and Havana, and the over-water route between Detroit and Cleveland has been regularly served by seaplanes during the past two summers, with a steadily increasing patronage. The great American achievement along the line of putting the airplane to work, however, has been the Air Mail service.

The Air Mail was started between New York and Washington during the war. As that route proved too short for full efficiency it was abandoned in the summer of 1920 and replaced by the transcontinental service, which has been functioning regularly ever since. Since every part of the route is covered in each direction on every week-day, the total distance covered during the year is a little under two million miles, the actual figure for the fiscal year 1922 having been 1,727,265. By flying under conditions which would, even during the war, have been adjudged quite impossible for airplanes, the percentage of reliability (ratio of distance flown with mail to distance scheduled) for the entire year has been raised to over 96 (for the fiscal year 1923) and the figure for the summer months has consistently been above 99. On several occasions a whole month has passed, and 150,000 miles have been covered, without a single uncompleted or seriously delayed trip. There are no recent official returns of the ratio of trips completed to trips scheduled on most of the European passenger lines, but it undoubtedly is, in all cases, somewhat inferior to the Air Mail's ratio. During the summer of 1921, for which complete statistics have been published by the British Air Ministry, the average percentage of the commercial airplanes operated by British companies was 95 on the London-Paris route and 89 between London and Amsterdam, despite the prevalence of fog over the Channel. It has been demonstrated very conclusively, both in Europe and here, although more effectively by the United States Air Mail than by any passenger line, that at least 95 per cent. of all scheduled trips can be completed on schedule time during eight months in the year, using the airplanes and other equipment now available. In strict adherence to a time-table the airplane need not fall far behind the railroad, although, to be sure, when the airplane is delayed by impossible weather or by a forced landing the delay is likely to be a long one. Such delays are becoming progressively rarer as the reliability of engines is improved and as better methods of navigation for flying in bad weather are developed. Every meteorological obstacle except fog has already been overcome, and progress is being made in conquering that.

Any further extension of commercial aerial transport facilities

must be the result either of the financial success of those lines which are operating already or of very conclusive proof that a profit can be made with some new line or some new scheme of operation. The governments of the world have so far lent direct support, for all the major and most of the minor states of Europe have offered subsidies, but that policy can not be pushed much further without excessive burden on the tax-payers. If air lines are to take a really important place among the world's means of transport they must be self-supporting.

The subsidies, helpful in some cases, have been definitely harmful in others. Since they have been given largely to encourage the aircraft industry and to build up a source of military equipment, many of the grants are hedged about by restrictions which force inefficient operation and the use of airplanes of a type quite unsuited for economical commercial use. They are having an effect not dissimilar from that of the French ship subsidy law of three decades ago, which had the effect of turning the clock backward and reversing the natural course of development by fostering sailing ships at the expense of those propelled by steam. Such a subsidy may satisfy the operators for the time being, but it offers no incentive to the search for improved methods and equipment, and it certainly does not represent the proper road to the upbuilding of a strong and self-reliant business. Furthermore, the very generosity of a subsidy may discourage efficiency and prevent an energetic search for traffic and attempt to stimulate public interest in flying. Where the state guarantees all expenses there is no reason to seek passengers, who must be cared for at the terminals with some expense and trouble and whose presence on board the aircraft involves the risk of suits for heavy damages in case of any accident, however slight. An exaggerated subsidy has the effect, also, of stimulating the creation of lines where there is no important public service to be rendered. An illustration of the extreme disproportion between some of the subsidy grants and the amount of actual business done in securing them is afforded by the case of a certain French company which, during 1921, received 6,419,000 francs in subsidies, and 529,400 francs gross from the public for the transporation of passengers, express and mail. It should be said, however, that this is not a typical case, and it is necessary to emphasize again that some of the air routes were selected for political reasons and have no economic excuse for being.

Even the most generous subsidies involve comparatively small expenditures, as national budgets now go. In 1921, for example, French air lines covered a total of 1,391,000 miles on a subsidy of 25,366,865 francs (about $1,800,000), and this year's recommended budget provided for a grant of 45,250,000 francs.

The rates on air lines at the present time under liberal subsidies obviously have but little significance, and in many instances they are fixed by the government quite without regard to the costs of operation. There are a few European countries, however, which offer only very moderate assistance in meeting running expenses, and two or three lines there, in addition to all those in America, are getting along with no subsidy at all. The British subsidy to all companies combined totals only £95,000 ($425,000), and the passenger rates on the various routes which those companies serve range from 3.8d to 6.6d (7c. to 12c.) per passenger mile, including 30 pounds of baggage for each passenger. The French, who are the beneficiaries of one of the most liberal subsidies, charge an average of 1 franc (5½c.) per passenger mile. German rates are, of course, still lower. They were equivalent to approximately 2 cents a passenger mile in the summer of 1922, but the recent gyrations of the currency make it futile to attempt the statement of any equivalent for the rate, either in marks or in gold. The German government itself has abandoned the effort, and now awards the subsidy in gasoline or the equivalent in currency at the price momentarily prevailing.

The higher of the two British rates quoted above represents about the best that can be done on a self-supporting line with at least ten passengers traveling each day in each direction and with airplanes of existing types. It has been the general conclusion of those who have analyzed the subject and prepared hypothetical balance-sheets with direct reference to American conditions that it should be possible, given that amount of traffic and operating twelve months in the year, to run at a small profit with a rate of from fifteen to eighteen cents a mile. The operations of the Air Mail have given invaluable testimony on that point, and have removed the estimates from the realm of pure theory, for very full reports of all expenditures, including departmental overhead and all salaries of officials in any way connected with the handling of the mail by air have been compiled each year. The actual cost per airplane mile has ranged from 70 cents to a little over a dollar, but in the year when the expenditures ran highest a large part of the outlay was for permanent improvements to fields and buildings. Eighty cents may be taken as a fair average. It is possible to build airplanes, using the same engine as that used in the Air Mail planes and costing no more to maintain, which will carry nine passengers besides the pilot. If a 78 per cent. load, or seven passengers per trip, be assumed, the per capita cost would be 11.4 cents a mile, and a rate of 16 cents leaves a 30 per cent. margin for selling expense and profit.

To reduce this cost, either the flying or the ground expenses must be reduced. While there are considerable possibilities in the first direction, possibilities in the production of airplanes of increased efficiency which will be realized with the further development of design, the greatest saving at the moment can be made on the ground. Air transport at present is being conducted on far too small a scale to be efficient. With one airplane a day in each direction, and an office force and staff of mechanics at each terminal and at every intermediate stop, the overhead becomes enormous. With seventy passengers each day, instead of seven, the rate should come down to not more than ten cents a passenger mile, or about double the charge on extra-fare trains in compensation for more than doubled speed. There should be little difficulty in getting business at that figure. The actual flying expenses of the Air Mail (fuel and oil, pilots' salaries, repairs to airplanes, etc.) so far as they can be segregated from other items are about 40 cents an airplane mile.

Only through large-scale operation, too, can one of the greatest advantages of air transport be realized. All high speeds in the past have been reached by the use of large units of conveyance. The fastest ships are the largest, and the fastest trains are the heaviest and longest of passenger trains. Only in the airplane can speed be combined with small size, and only the airplane permits of operation of high-speed vehicles at very short intervals. The present demand only justifies the operation of two extra-fare trains a day between Boston and New York, but one fourth the number of passengers carried by those two trains would fill a nine-passenger airplane every 40 minutes during the business day. The gain in usefulness to the business man would be inestimable, but it is essential, if the American people are to take advantage of the possibilities of aircraft, that the development of air transport be taken up and fostered by interests of sufficient financial strength and far-sightedness to provide the capital needed to start operations at once on a scale large enough so that the airplane service will always be available within a few minutes of any desired time and so that it may present a real saving over the train. There are routes in America where there is a clear need for such a service to-day.

The airplane alone has furnished the data for this brief treatment of the economics of air transport, and there has been but little experience in the commercial utilization of any other type of aircraft, but the airplane will have to divide the field in future with the lighter-than-aircraft, the airship. Technical limitations are such that it is not now possible to operate the airplane for more than 300 miles non-stop with reasonable economy and commercial efficiency, nor does it seem likely that that limiting distance will be

very much increased in the future. The airship, on the other hand, can easily make voyages of three or four thousand miles with a good commercial load, and it will have to form the chief reliance for trans-oceanic aerial travel. It is to airships that the British are turning for the projected London-Australia service.

The load carried by the airship for every unit of power is considerably greater than the corresponding figure for the airplane, and operation is correspondingly cheaper, despite the added item of replacements of gas. Although there is little experience on which to base an estimate, and will not be, in America at least, until the Navy publishes the figures which are to be obtained with Shenandoah and the ZR-3, it is probable that a passenger rate of seven cents a passenger mile can be maintained. With an allowance of twenty dollars a day for meals, service and other "hotel expenses," the cost of a two-day trans-Atlantic passage would hardly exceed the first-class charge on a six-day boat, although it must be admitted that the accommodations would at present be somewhat inferior in luxury to those on the liner.

Whether the airplane or airship is under consideration, there is one form of assistance which must be secured from the government, and which has no relation to a subsidy. It is impossible to operate without landing fields, maps; it is impossible to fly regularly and safely without meteorological reports broadcasted by radio, and other aids to navigation, generally grouped with the landing fields under the title of "ground organization." The provision of these things, which will be available for all who fly and will be used by all, is solely a government function, as surely as are the establishment and maintenance of lighthouses along the coast, the dredging of harbors and the publication of charts. To propose that some company should assume the whole burden, even on a single route, can only be described as preposterous, and there is unlikely to be any regular commercial flying on any overland route which has not had the benefit of some governmental development. The entire absence of overland air transport in America to-day is chargeable primarily to the unwillingness of Congress to give attention to the needs of commercial aeronautics and to the economic possibilities of aircraft.

Important as is ground organization for all regular commercial operation, it is the absolute condition of existence of night flying. Obviously, aircraft will not render the full benefits of which they are capable until they can give a twenty-four hour service, with over-night travel from New York to St. Louis or Chicago to New Orleans. So far as the airplane and its pilot are concerned, there is nothing to hinder night flying at this moment. The Air Mail

has proved conclusively by actual demonstration that an airplane can be flown by night with substantially the same safety and certainty as during the day, but only on condition that aids to navigation are provided. Although the airplane itself carries lights which are of great assistance, and avoid the necessity of flood-lighting the whole area of the landing field to a uniform brilliance when a landing is to be made, it is still necessary to place lights around the edge of the field to define its boundaries and to warn the approaching pilot of any local obstacles such as buildings or flagpoles. Such provision must be made not only for the regular terminals and fueling stations but also for intermediate emergency fields permitting landings in case of engine trouble.

Night-flying organization must include the marking of the route as well as of the fields. Aerial beacons must be established every twenty or thirty miles, each throwing aloft a beam of such intensity that the pilot can rely on having at least one light always in sight. The provision of such lights bears a perfect analogy to the safeguarding of our coasts by lighthouses and buoys, and the government which has long provided for sea and lake traffic will have to do as much for the voyagers of the air. One experimental route, that between Chicago and Cheyenne, has already been equipped, and it was over that route that the Air Mail's experiment of last August, during which a continuous day-and-night service from coast to coast was maintained for a week, was made. The experiment succeeded in every detail, but the night service could not be continued because of lack of funds.

Experiments in night flying during the past year have served to concentrate attention on the use of aircraft for express service. Airplane design has not yet progressed quite to the point of offering comfortable sleeping accommodations. That development can be foreseen for a future not very distant, but for the moment it is easier to use existing types for the carriage of cargo when all-night travel is involved. Express matter can be carried between New York and Chicago at sixty cents a pound, with collection in one city late in the afternoon and delivery in the other early the next morning. The rate is high, compared with that by train, but the saving of time would more than justify the difference of cost for certain classes of goods which now go by train, and if 2 per cent. of the express traffic which now travels by rail between the two cities were to be diverted to the air routes it would require the operation of half a dozen 400-horsepower airplanes in each direction every night. Already officials of one of the great express companies have declared themselves willing to cooperate in securing business for the airplanes and in handling collections and deliveries through their existing organization.

In view of the probability of an early development of aerial express service in America, it is of interest to observe the trend in that same direction in Europe. Although the use of the air lines by passengers has, as already shown, been steadily increasing, their use for mail and express has in general advanced even more rapidly, especially on those routes which seem likely to make but little appeal to passengers. The passenger business between France and Morocco, for example, is almost negligible, but the weight of goods carried has rapidly increased until, in 1921, it totalled about 35 tons, for the whole year, while in June and July the present year the mail and express for the two months amounted to over 20 tons. In April and May, 1922, the total weight of the express and mail matter handled by the French air lines running to and from Paris was 198,700 pounds, while the corresponding figure in 1923 was 349,000 pounds, an increase of 76 per cent. Between the same two periods the passenger traffic on the same lines increased only 13 per cent. The absolute figures are still small for all classes of business, but the upward trend of the curve is unmistakable.

That last statement, indeed, epitomizes the situation. The public has been slow to accept air transport, but there is ample evidence to show that progress is being made, and that the airplane is gradually coming to be regarded as a commonplace vehicle for the conveyance of ordinary people and their goods in the ordinary course of business. We shall have occasion for profound regret if America, the original home of the airplane and a country always known for its quickness to adopt the improved method in transport and in industry, continues too long to lag behind the other nations of the world in the exploitation by private enterprise of the commercial possibilities of aircraft.

PASTURE

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I

PASTURE—and the seeking after fresh pastures—has always been a fundamental motive in man's history. In the mist that shrouds that ancient world of men, which we of to-day call the "prehistoric," certain tribes were wandering with their flocks and herds out of some eastern land—Egypt, Moab, the "fertile crescent" of Mesopotamia and Palestine, the plains of Trans-Caspia—northward and westward into Europe, moving slowly, century after century, always in search of fresh pasture—in the dawn of history. These ancient shepherds and herdsmen were a neolithic folk, using stone implements, polished and ground to fine edges and points, and in later times working out the same patterns in copper and still later in bronze, but all the while pastoral by nature. The most familiar record that has come down to us of the life of some of these tribes is that depicted in the early Hebrew Scriptures, where the wars were essentially wars for fresher and more extensive pastures. The life of these peoples revolved about their flocks and herds and their language was filled with pastoral allusions—the lamb as a burnt offering on an altar of stones, the blood of bulls and of goats, the ashes of a heifer, a land flowing with milk and honey, green pastures and still waters—all such expressions could only have come out of the life of shepherds and herdsmen.

In their far-and-wide wanderings the vanguard of these neolithic and bronze men encountered a ruder hunting folk, men who hunted the aurochs, the red deer and the horse, who still followed the retreating herds of reindeer to the north and killed the last remaining mammoths with their rough stone spears and javelins. The short space of written tradition which we regard as history is but as yesterday compared with the thousands of years during which the pastoral peoples spread over Europe from the east in successive waves of migration, seeking—always seeking—new pasture. In Asia Minor their herds of sheep and goats are thought by some writers to have nibbled and tramped down the grass to its very roots and to have thus, in a land of little rain, prepared the way for the encroaching sands that made deserts of once fertile regions and forced the grazing herds to move towards lands of more abundant grass. In those prehistoric millennia the pastoral nomads in Europe no doubt long dwelt in the midst of the hunting peoples,

the remnant of the old "reindeer men" of paleolithic culture, as settlers in a wild land have always dwelt surrounded by savages—in North America and in Africa. The once glacial meadows of Central Europe were covered with lush grass, with buttercups, daisies and other wild flowers—rich pastures for the increasing flocks and herds of the invaders and, as has always been the case in every land and age, the wild animals dwindled and the primitive hunting life gradually disappeared as a dominant feature.

The question of pasture has always been of vital concern in the life of a hunting people as well as in that of the herdsmen. A fundamental factor in the evolution of the human type, wherein it broke away from some anthropoid stock of entirely vegetable feeders, was the acquirement of a more general diet into which the flesh of animals largely entered. At first a feeder on carrion, man gradually took to killing the large herbivorous beasts that roamed in herds over the land, and the wanderings of these game herds in their search for new pastures governed the movements of the primitive hunting population. Wherever the wild herds pastured, there were hunters on their flanks, wandering far and wide as the game shifted from one territory to another, and the earliest records of human history are in the rough spear heads and stone axes of the hunter's craft. In whatever area of the earth man originated he spread from this early cradle of the race with the grass feeders, slowly widening his range until every portion of the great continental land masses was occupied. America was thus undoubtedly peopled by some primitive Asiatic group that wandered with the deer and the bison herds, and quite likely, too, with early elephants like the mastodons, across the Behring land-bridge. It has ever been the lure of pasture in human history.

The influence of pasture began long before man's advent upon the scene. Had it not been in the scheme of plant evolution that the grasses came into existence there might have been a very different creature than man as we now know him. Not until comparatively late geological time did the grass type appear and also flowering plants like the vetches and clover, the crowfoots, heaths and compositae, which with the grasses cover vast areas of the earth. Without this abundant food-supply, rank and deep and forever renewed, the great mammalian fauna could not have come into existence. In the scheme of evolution man thus appears as one of the results of pasture.

II

Undoubtedly the most far-reaching achievement in human history, next to the discovery of how to kindle and keep a fire, was the domestication of certain species of grazing animals. In what way

this was accomplished is entirely a matter of conjecture, for it is lost, as the beginnings of so many human faculties are lost, in the dim twilight of the ancient world. The outstanding feature of this achievement of the primitive genius is the fact that no other wild stocks have ever been domesticated within the ken of recorded history, not a glimmer of tradition even has been vouchsafed to men of later times as to how it came about. It must be regarded as a trait of the primitive mind. If we choose to speculate at all on these origins and the absence of any later effort to tame and use other wild stocks we might possibly view their problem from one or more angles; either it came about by the capture and raising of the young of certain species and the subsequent discovery of useful qualities in a more or less accidental way, or, by a process of reasoning, primitive men deliberately set about to capture and tame individuals of several species with the view to making use of them in advancing human welfare, and that domestication once established there was no further need for any new additions. There is archeological evidence to show that domestication of some animals came to an end and was never again attempted. In certain Egyptian reliefs several kinds of antelopes are depicted as being "stall-fed," and the species are clearly recognizable, all natives of Northern Africa. On the tomb of Mereruka at Sakhara (twenty-seventh century B. C.) these are shown as tied to their mangers, and likewise on the tomb of Kegemni of the same century mention is made of "stables of the plateau antelopes." What use these animals were put to we have no means of knowing.

There is no doubt but that pastoral life developed out of a hunting life, the animals domesticated having been originally hunted for food. All we know is that the wild ancestors of most of our domestic stock have absolutely disappeared, merged probably in their entirely domesticated descendants. Some light is thrown on this by archeological researches in Egypt where a primitive hunting people during late paleolithic times (men who were contemporaneous or even earlier than the cave men of glacial Europe) appear to have begun the process of domestication of certain bovine species and also of the wild steppe ass of Nubia. Predynastic reliefs of a date not later than the fourth millennium B. C. show cattle, sheep and donkeys, species which even at that time must have been long under domestication. The antiquity of domestication in Egypt is further attested by reliefs showing a milking scene and also of a hornless breed of cattle (tomb of Ti at Sakkara, 28th century B. C.). Now the abstraction of milk from an animal by the hand of man would surely argue for a very long period of domestication. Several wild stocks may have contributed to the ancestry of our

pasture animals. From the beginning they have been an integral part of man's existence; without them we can not conceive of human history as an advance from lower to higher estates. Their reaction on agriculture was of the first importance. Egypt, that storehouse of antiquity, reveals in its reliefs how the primitive hoe was converted into the ox-drawn plow (plowing scene from tomb relief, 26th–27th century B. C. in the Louvre, Paris).

The relation between agriculture and the pastoral life has a far deeper significance than the effect on implements and methods. It lies at the very roots of the social state. In primitive times woman was the agriculturist and it was by her labor that the earth was first made to yield its increase. About her rude home she scratched the soil, sowed the gathered seeds of various wild plants and thus grew the earliest kitchen garden which insured food for herself and her children. It was she who first most likely domesticated the dog by the care and nurture of the puppies of some wild wolf-like animal that from time to time were brought into the home by her men, even suckling them, as has been observed among some tribes in Australia and America and as related in certain aboriginal tales where a dog is spoken of as a foster-brother. When it came to taming the great beasts of the pasture, that was a man's job and was the foundation of the patriarchal stage of society. In primitive times the social state was a matriarchate or mother-right, but as the pastoral life became more and more a dominating feature in the life of the early Asiatic and North African peoples and hunting became supplementary, pursued against predatory beasts and for sport, man acquired an increasing interest in agriculture and slowly took over much of the woman's share of primitive husbandry. In doing this he also took over the woman herself as a possession and she became part of a social state in which the family was a unit governed and controlled by the man. Traditional history opens with this patriarchal stage, the nomadic shepherd and herdsman being a chief at the head of some clan of several families united by blood, continually clashing with neighboring clans for pasture rights. With this power vested in the man polygamy was a natural consequence, for the more children a man had to tend the sheep and cattle, and sons to aid in the primitive warfare, the larger would be his herds and flocks and the wealthier and more powerful he became. The abundance of milk furnished by the herds was a further cause of family increase, insuring a steady and sufficient food-supply for young children. In nomadic life a man's household was maintained and grew in proportion as he was able to extend his pasture. The word "daughter" bears witness to a primitive division of labor in the patriarchal family—"a milker"—the eternal

goddess of the herds in every age and generation, milking her cattle in byres and on the edge of pastures, at daybreak and in evening twilight, since the dawn of history.

III

Walter Pater somewhere speaks of "that strange mystical sense of a life in natural things, and of man's life as a part of nature, drawing strength and color and character from local influences, from the hills and streams and natural sights and sounds."[1] In nothing is this more real than in things pastoral. A love of pastures and the life of pastures is our natural inheritance. The spell of wild lands may hold us for a time, but the call of the pasture is ever in our blood and we come back to it as a child to its mother. The smell of grass is as the very breath of our nostrils. In pastures, as in gardens, the soul of man finds delight. It may be among the hills where the pastures slope up to the sky-line—rock-strewn uplands with their stone-wall boundaries and the trilling of vesper sparrows heard in lulls of the wind, or in deep-grassed meadows through which some quiet stream meanders. Izaak Walton was a lover of such meadows and "The Compleat Angler" is as much a call to pastures as it is to fishing. Listen to this opening verse of his "Angler's Wish":

> I in these flowery meads would be:
> These crystal streams should solace me;
> To whose harmonious bubbling noise
> I with my angle would rejoice . . .

And again in "The Milkmaid's Song," by Christopher Marlowe, which Walton has Maudlin sing—

> Come live with me, and be my love,
> And we will all the pleasures prove
> That valleys, groves, or hills, or field,
> Or woods and steepy mountains yield;
>
> Where we will sit upon the rocks,
> And see the shepherds feed our flocks
> By shallow rivers, to whose falls
> Melodious birds sing madrigals.

In the high Alps there are pastures that creep up to snowfields and the edges of glaciers, friendly and home-like places among the stark peaks. And there are the great unfenced pastures of the world—the African veld, the pampas of Argentina, the prairies of

[1] Preface to "Studies in the History of the Renaissance."

North America, the Central Asiatic steppes, where the herds of man wander half wild and often in sight of strange beasts. Our settlers on the prairies fifty years ago and the early Boer farmers in South Africa were witness to this stirring contact with the wild life. Gordon-Cumming, when living in Cape Colony in the first half of the last century, relates how one evening when his man was bringing in the cows to be milked four lions appeared on the edge of the pasture—an exciting event but not an uncommon one on South African farms at that time and even to-day in such regions as British East Africa and Northern Rhodesia.

This touch of wild life is in every pasture. The wary fox crosses the open stretches of grass and will sometimes stop to dig out a field mouse. On mountain farms in old settled districts a bear occasionally shows himself along the forest border of fields where cattle and sheep are feeding. Old Peter Little once told me, as we stood by his house in a hemlock clearing up in the Pennsylvania mountains, that when he was a young man wolves killed the stock on that same mountain farm, and he swept his hand towards the edge of the woods where he had seen them skulking in the dusk. The woodchuck still makes his home in our pastures, scuttling into his burrow at sight of us, and the skunk and weasel peer out from bordering thickets. Since the country has become domesticated many kinds of birds frequent the grasslands—the call of the bobwhite in early summer is the very spirit of old pastures, the meadow lark flushed from grassy cover, the killdeer wheeling about with its wild cry, the strange cowbird walking among the cattle, the scattering flocks of grackles and redwings in autumn and their return in early spring, the crows foraging in winter—all have the pasture as a background and help to cast that spell, that mysterious feeling of delight, of release from the sordid things of life which the true lover of the countryside knows so well. And the same is so with the pasture blooms—the white patches of spring beauties and bluets, the later gold of buttercups, the meadow-sweet and the daisy crop, the blue iris in moist places, lavender-topped grasses, hellebore and St. John's wort, and the rank pasture growth that comes at the end of summer—iron-weed and boneset, the milkweeds and thistles, the lobelias and gentians, and along old fences and stone walls the autumn-blooming asters and goldenrods. These later blooms of the pasture exhale a peculiar fragrance, heavy and medicinal, that stirs up something in the subconscious that is indefinable but altogether delightful. It is a part of that strange magic which reveals the kinship of man with natural things—with what William Sharp calls the "green smell of grass," with freshly turned plowland, and the smell of woods.

Certain races are countrymen at heart, even though the vast majority are doomed to dwell in cities. The old American type, the stock that sprang from the loins of western Europeans in the seventeenth century, has this fortunate heritage—the love of land and of open country. Agriculture first induced permanent settlement in certain fertile river valleys, and centralization in cities was a natural consequence, for man has ever been a buyer and seller of commodities. But the most ancient coin carried the stamp of an ox on its face, and this meant pasture. The grass and grain crops have always been grown to feed the herds, to carry them over periods of shortage when the fresh grass was scanty. Animal flesh and milk have largely made man what he is, but it is the pasture, after all, that enters into his being—by his very nature he is part of it. It is this that is the real life of man—this ancient thing foreordained to bring about the human type. "All flesh is grass" has thus a deeper meaning than that of a transient existence which it was intended to symbolize. It is man himself, and not only his bodily organization but his mind also is an expression of this fundamental relation. It comes to many of us as an interest in the animal life of the world of which men are but a part; to some it is a love of woods and fields, of old farm holdings on hillsides and in valleys, of wide prairie lands and wild places of the earth. The artist and the poet tell of this feeling on canvas and the printed page. In every man who is alive to these influences there is established in his soul something that is primitive and which endures—some sight or smell or sound that recalls the agelong intimate relation of his race with things pastoral.

SOME HISTORICAL ASPECTS OF EXPERIMENTAL PHYSIOLOGY

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As is well known by students of the history of science, the extensive use of the experimental method as an agent with which to find new truths began during the early decades of the nineteenth century. To be sure, definite experiments were resorted to by many scientists before this time, notably Galileo, who experimented with the pendulum, Newton, who studied the dispersion of light by a glass prism, and Harvey, whose classical investigations led to the discovery of the circulation of the blood. Such instances, however, were unusual rather than common and, if viewed from a sociological standpoint, may be regarded rather as the expression of that surging spirit of unrest suffering repression, which Rousseau has so aptly expressed in the words, "man is born free and everywhere he is in chains." The number of men in any one century before the nineteenth who thus rebelled against the sway of ignorance and strove to overturn its rule was small; compared with the number of those who thus labored during the past one hundred years, it seems to become very insignificant indeed.

Such a condition is not difficult to understand, however, when the social fabric of those earlier centuries is considered. Reverence for authority was to be found in the field of medicine and biology as well as in the domain of theology. This fact alone should teach us how remarkable is the hold and influence upon all society of such intangible things as the psychological factors in life, "modes of thought," "social complexes," "mores," or whatever one chooses to call them. For nearly fifteen hundred years the physiological concepts that were taught were those of the great Roman physician Galen. Vesalius in 1542 was the first to protest against Galenic authority in anatomy when that authority failed to agree with anatomical truth as revealed to the naked eye by skillful dissection; but in spite of the emphasis which this gifted man placed upon accurate observation of nature alone, so few were the workers who used the scientific method even moderately that the world had to wait for nearly seventy years before such an individual appeared in the person of Harvey, who solved by definite and carefully planned experiments the great mystery of the passage of the blood from the right to the left heart.

Previous to the nineteenth century physiology as an independent science did not exist. During the eighteenth century and earlier this subject was taught as a phase of anatomy, the function of organs being discussed by the teacher at the same time that the structure was being studied.

Stenson, whose "Observationes Anatomicae" was published in 1662, referred to the physiological studies, of which he was cognizant, as *anatomical experiments.* In an appeal on behalf of the practical value of science he said:

> It may be shewn abundantly elsewhere how much medical practice owes to the anatomical experiments of this age, even if it were only for this that they have exposed the numerous errors which occur in the explanation of the causes of disease and at the same time shewn the reasons which have governed the application of remedies to be in most cases erroneous. To those who decry the value of science I would give as an answer this demand that they should ask their own consciences and see what solid basis there is for all those dogmas which they pronounce with such bold ease when they explain the symptoms of apoplexy, paralysis, convulsions, prostration of strength, syncope, and other diseases affecting animal movements, on what foundation they rest when they apply remedies for removing these evils, with the result that they do away not with the paralysis, not with the convulsion, but with the paralytic or the convulsed man.[1]

As is the case to-day, one of the important posts in the medical schools of that early day was the chair of anatomy; a survey of the various medical schools of the time of Boerhaave and Haller indicates that any teaching of what is now understood by the term physiology was done by the professor of anatomy. Even Haller, who is now remembered as the immediate forerunner of modern physiologists and a great student of the functions of organs, made his living teaching anatomy, first in his native town, Berne, Switzerland, and later at the University of Göttingen, which George II of England, also Elector of Hanover, had just founded.

Haller's own published works furnish an excellent example of the close relationship which existed between anatomy and physiology and the dependence of the latter upon the study of structure as the *raison d'être* for its own study. Göttingen was provided with a very good anatomical theater, and from dissections made there Haller produced a set of most beautiful anatomical drawings which he published between 1743 and 1753. Vesalius had published his famous "Structure of the Human Body" a century before (1542), and even Haller's master Albinus had made drawings of interest to anatomists. These earlier works, however, were comparatively coarse, those of Vesalius made so because that master

[1] Quoted by M. Foster, in *The History of Physiology,* p. 285. Cambridge University Press, 1901.

had no microscope, and those of Albinus because only separate parts, such as a muscle, a nerve or a vein, were drawn. In Haller's plates were first shown the different nerves and vessels attached in their right position, and—what is most interesting—to each plate was added a complete account of the *function* or use of the part drawn. Haller's drawings were so accurate and full of detail and required so much time to prepare that in seventeen years, with all the help he had, he was not able to complete the description of the whole human body.

The word *physiology* comes from a Greek word which may also be translated as *natural philosophy.* Among all the many sciences which have developed from the scientific renaissance of the nineteenth century as offshoots from what was formerly called natural philosophy, physiology alone has continued to use the old mother term; in this particular instance, however, the word has been retained but with its meaning greatly altered. When one endeavors to determine the precise origin of the modern science of physiology by fixing upon a definite date or individual or discovery, he meets with a real difficulty: if his own scientific training has been essentially in or closely related to the field of chemistry, he may regard Lavoisier as the real founder of modern physiology; on the other hand, all the German students of the history of science have seen in the person of the great Johannes Müller the first of the really modern physiologists.

While such uncertainty appears to envelop the origin of this science, much interest does attach to the fact that in 1824—one hundred years ago—appears to have been given the first course of instruction in anything like what is now understood by the words *experimental physiology.*

In 1822, a young Bohemian scholar, Johannes Evangeliste Ritter von Purkinje, was called from a lectureship in anatomy at Prague to the chair of physiology at the University of Breslau. This young teacher, after following for two years what was to him the old-fashioned method of teaching this subject, decided to change the method. What greatly impressed Purkinje was the lack of any really exact knowledge concerning the functions of organs and the predominantly theoretical and speculative character of all work in this field. Few if any original experimental investigations were being made in physiology anywhere; the theories of Boerhaave, Haller and other old masters formed the subject-matter of discourses in this science. In 1824, therefore, Purkinje began illustrating his lectures by a variety of experimental demonstrations in order that he might arouse among his students an interest in physiology as a subject quite worthy of study for its own sake. So far

as can be ascertained, this was the first course in anything like experimental physiology.

As has so often been the case, this great heritage in science had its beginning under rather inauspicious circumstances. The available class rooms were not suited for such work as Purkinje wished to do. At first the demonstrations were held in a small room attached to the department of anatomy; later the physical laboratory was utilized for this purpose. In 1831 Purkinje asked the authorities to erect a special building for physiology, and this request was refused. Discouraged and despairing of finding a home for his growing subject in the laboratories of the university, Purkinje gathered up his instruments and departed with them to his home, where under most unfavorable conditions he contributed to the establishment of physiology as a separate science.

In 1830, after the university had refused to purchase a compound microscope for the physiology department, Purkinje, with the assistance of friends, secured one himself at a cost of fifty dollars: it was with this instrument that he first noticed the large cells of the cerebellum which bear his name.

Purkinje studied a variety of problems in the fields of physiology and anatomy. In 1823 he described the now well-known method of investigating the structure of the retina by observation of what is seen after a flame has been waved beside the eye; two years later, in a study of the origin of the bird's egg within the ovary, he made the important discovery of the germinal vesicle, which came to be known for a long time as the "Purkinje vesicle." His contributions to histology included descriptions of the structure of bone, cartilage, blood vessels, glands of the stomach and the ducts of the sweat glands, and culminated, from the standpoint of the interest aroused, in his announcement in 1837 at a meeting of naturalists in Prague of his discovery of the axis-cylinder of nerve cells. At this same meeting he expressed the opinion that the interior of many organs is composed of cells and nuclei, an opinion which may be regarded as a foreshadowing of the cell theory which Schwann's investigations definitely established only a few years later.

All these discoveries, together with Purkinje's growing fame as a teacher, led finally to the establishment by the government in 1839 of a separate institution for the teaching of physiology and for physiological research. For twenty years after his dream had thus been realized, this great teacher and investigator labored at Breslau. His service as an advocate had been successful; physiology had indeed come into her own.

Perhaps it would be an exaggeration to say that Purkinje's work at Breslau was the leaven which developed the loaf of physiology

in Europe; doubtless many other factors contributed to promote interest in the experimental side of this subject. The experimental method was being used extensively in other fields of endeavor, and each great discovery resulting therefrom in physics, chemistry or biology only served to give impetus to the forward movement which the scientific spirit was making. Mere mention of the fact that among Purkinje's contemporaries were such men as the chemists, Berzelius, Dumas, Liebig and Wöhler, the great mathematician and physicist Helmholtz, and the biologists Magendie, Schwann, Johannes Müller and others, should suffice to indicate how much the development of physiology after 1824 was due to a great wave of scientific endeavor which gained in power as each decade passed. With the growing interest in the search for new facts concerning the physical universe, physiology, together with the other sciences, profited, new institutions for the study of functions of organs developed and other illustrious names appeared in this field, among them Du Bois Reymond at Berlin and Claude Bernard at Paris. A detailed account of the advance in the field of physiology made after the establishment of the institute at Breslau would fill a large volume and would be essentially the story of modern physiology; certainly, after glancing over the accomplishments made during the past hundred years following Purkinje's course in experimental physiology, few will be found to deny that in this case at least "wisdom is justified of her children."

It is of interest to know something regarding the later history of the institute at Breslau. In 1859 Purkinje resigned his professorship and returned to Prague, where he took an active part in Slavic national movements and politics and gradually withdrew from endeavor as a scientist. His successor at Breslau was a young man, twenty-five years of age, Rudolph Heidenhain.

The fame which the Breslau Institute achieved under Purkinje's directorship was in no way dimmed in later years when Heidenhain was in charge. This great teacher and investigator, to use the words of Professor Carl Voit, "soon began and ever after displayed a fruitful scientific activity and trained many students to whom his conscientious and unflagging zeal for the work was an inspiring example; in such a manner did he fulfill the confidence placed in him to the highest degree." His studies of secretion were masterly, and included not only observations of the phenomena of secretion but histological examinations of gland cells both in a resting and in an active condition. The Heidenhain monograph concerning secretion, which forms a large part of the fifth volume of Hermann's Handbuch der Physiologie, is one of the classics of physiological literature. During these days of 1924 when over-specialization and

independent activity seem to be unduly emphasized and appear in some measure to affect the quality of research being done, Heidenhain's method of studying secretion may teach a lesson of the value of cooperation and completeness in physiological research.

Under Heidenhain's inspiration the great Russian school of physiology was founded. Pawlow's remarkable studies of digestion, for which he received the Nobel Prize, involved in part a method of operative procedure which was an improvement on a method devised by Heidenhain. Thus may the Pawlow laboratory at the Imperial Medical Institute at Petrograd and all its interesting contributions to physiological knowledge be regarded as the offspring of the Institute at Breslau.

Heidenhain's influence extended also to other parts of Europe and even to America. The prominent English physiologist, Professor Ernest Starling, now at University College, London, received his training for the study of problems concerning the lymph from the Breslau master. Among the American students who thus received inspiration for their life work may be mentioned Professors W. T. Porter of Harvard and Lafayette B. Mendel of Yale University.

How does the future outlook for present-day physiologists compare with that which Purkinje must have visualized? Of course one can only speculate as to what the Breslau teacher must have thought as to the possibilities in the scientific study of function. That new and important generalizations would be made, he must have realized, for we know that he was learning to think in terms of the cell theory several years before Schleiden and Schwann definitely established this conception. Purkinje's scientific career was full of achievement, and that fact alone may be taken as indicating that his was an active mind alive to the possibilities in this field and anxious to realize them.

Present-day physiologists frequently hear a note of pessimism regarding the future outlook of their science, usually from students who have not been taught the directions along which physiological advances are being made and stimulated to feel that they are caught in a great current of enthusiasm which will carry them on to new and worthy accomplishments. Surely the present outlook may be regarded every bit as promising as that which physiologists living a century ago faced. It might safely be said to be even more promising, for the circle of knowledge—to use Herbert Spencer's figure—has become much larger and the number of points at which the known touches the unknown outside the circle of circumference has correspondingly increased. A host of problems still remain to be solved; the vast majority of them have come into being simply

as a result of discoveries that have already been made. New interrelationships of organs remain to be learned; the mysteries of many ductless glands are still with us; the rôle of such an unsuspected factor in nutrition as sunlight furnishes numerous problems for the detective in physiology to unravel. These are only a few of the many possibilities of service for the advancement of physiological knowledge which are still open. Given the scientific insight which Purkinje had, and a similar undaunted spirit which insists on finding a way around obstacles, there is no reason whatever why the twentieth century physiologists can not hand on to their successors of the next century a heritage of achievement as large and as worthy as was received by them from Purkinje and his contemporaries, Heidenhain, Bernard and the many others of the past hundred years.

THE ORIGIN, NATURE AND INFLUENCE OF RELATIVITY[1]

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II. THE NATURE OF SPACE AND TIME

WHILE the historical survey of the development of the concepts of space and time is of essential value, only a direct logical analysis on the basis of the known experimental facts gives a satisfactory understanding of their real nature. Such an analysis indicates clearly why the space-time of relativity can be considered more nearly adequate than the classical space and time, and yet equally concrete and simple. As a preliminary step in this direction, the elementary facts of everyday experience will be stated independently of any particular theory. These are the same, whatever ultimate theory may be required to explain the physical universe down to the last ascertainable detail.

A fundamental characteristic of everyday experience is its arrangement in the order of time. Sensations are experienced in succession, and are recalled in the same succession as that in which they were experienced. There is also a flow in external nature nearly parallel to the flow of the stream of consciousness in the individual. Indeed, for the events which come within the range of immediate personal experience, sensations and the corresponding events are correlated in time without further question. It is true that occasionally a slight readjustment of this naïve interpretation is required, as when thunder follows lightning and it is realized that sound takes time to travel. Owing to the extraordinarily large velocity of light, it is never necessary to make an allowance of the same sort for light in ordinary experience.

It is very important to grasp the truth that a complete and exact parallelism between sensations in the individual consciousness and events everywhere throughout the physical universe, implying absolute simultaneity, can not be established in any simple way. For example, the attempt to correlate events as happening when seen was abandoned when the successive eclipses of Jupiter's satellites were observed to take place at smaller intervals of time when Jupiter and the earth were approaching one another than when receding. This anomalous result was accounted for by Römer in

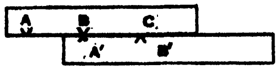
[1] Lowell lectures.

1675 by means of the finite velocity of light. The complete failure of such a correlation of events is brought out even more clearly by a hypothetical experiment like the following. Imagine that two observers *A* and *B* on two mountain tops, at a distance of one hundred miles from each other, send out flashes by means of revolving mirrors so that *A* sees *B*'s flash simultaneously with his own. Then *B* will see *A*'s flash about one thousandth of a second later than his own, and not simultaneously.

Thus it appears that the notion of absolute simultaneity of events requires physical definition by means of a technical process, and will have real meaning only if that process is unique. Our preconception that there exists such a significant correlation of events is based on the illusion of everyday experience that events happen when seen.

With these reservations, the notion of measurable time on the earth, call it earth-time, may be accepted as a working hypothesis. This time is measured with maximum precision by means of clocks at rest on the earth. Highly technical methods are used for synchronizing clocks far apart on the earth's surface.

In the stream of consciousness external objects called material bodies are identified and have a peculiar permanence. Among these are various nearly rigid bodies, possessing nearly constant size and shape. A piece of steel furnishes a good example. The comparison of such bodies by direct superposition leads to the concept of distance as determined by means of the ruler. In fact, take two simple rigid bodies of the very special type called straight edges. These can be exactly superposed in a variety of ways, and in particular so that any point of one coincides with a prescribed point of the other. Now let *A* and *B* be two points of the first straight edge, and let *A′* and *B′* be the two superposed points of the other. Place *A′* on *B*, and let *C* be the point of the first which falls at *B′*. Thus



we can mark the set of equidistant points *A*, *B*, *C*, . . . on the first straight edge, which can now be used as a ruler for measuring distances. Likewise, it is possible to construct a protractor for measuring angles. The laws of Euclidean geometry embody the results of approximate measurement in most convenient form. These laws are not to be taken as exactly applicable, particularly since no bodies are completely rigid.

An elaboration of these geometric ideas, in which the earth is taken as a rigid sphere of reference, gives rise to what may be called

earth-space. The position of a body in earth-space may be specified by giving three spatial numbers, *e.g.*, latitude, longitude and distance above sea level.

These systems of measurement of earth-space and earth-time may be usefully combined. Any terrestrial event may be completely specified by naming the instant of earth-time and the point of earth-space with which it is identified.

It is also evident from everyday experience that light is derived from definite material bodies like the sun, and occupies straight lines in earth-space in accordance with simple optical laws.

A physical theory will be held reasonable by the layman if it explains these properties of space, time and light, as well as any further physical facts that may have come to his knowledge.

Our concern is not with such a superficial explanation of the obvious facts of everyday experience. It is entirely with that fundamental kind of explanation which aims to provide a complete and exact account not only of these facts but also of those discovered by the more searching processes of the laboratory and observatory. How was it possible to advance in astronomy except by means of geometry which makes precise the spatial intuitions, and by use of the telescopic lens shaped with an infinite care so as to supplement the feeble powers of direct observation? By such means the physical universe has been found to be subject to highly exact law. As far as the underlying theory has been revealed to man, it appears ever more unified and grandiose.

Let us turn then to examine spatio-temporal law in some such spirit. It is well to begin here also by stating what are conceived to be the facts in the theory of absolute space and time hitherto accepted, and what are conceived to be the facts in the theory of relativity. In this way it will appear that there is a great deal in common to both, so that the divergences are minor by comparison and the new theory is equally simple and concrete. After so doing it will be possible to give intelligent consideration to the question of the logical analysis of space and time.

According to the classical theory there are two principal conditions which must be satisfied before the spatial comparison of material bodies (taken to be at the same temperature) becomes possible in any exact sense. All bodies in nature are elastic. Even a piece of steel lying upon a table is flattened by the force of gravity. Consequently, a first condition is that the bodies are small and at a great distance from any large bodies, so that such gravitational distortion is negligible. Furthermore, if such bodies are in a state of rotation, a similar condition of distortion will ensue because of the so-called centrifugal forces called into play. Hence it is necessary further

that there be no rotation. Under these favorable circumstances the body may be said to be undisturbed. When two undisturbed bodies are placed in contact they will continue in contact, and exact measurement by superposition becomes possible. The laws of Euclidean geometry will then be found to hold with maximum exactitude, according to the classical theory.

It is precisely the same in the theory of relativity. Small bodies at a considerable distance from any large one may not be rotating, so that no centrifugal forces are called into play, and then may be said to be in an undisturbed state. When placed in contact their measurement by superposition becomes possible, and the laws of Euclidean geometry will hold with the same degree of exactitude.

Even so, the degree of accuracy to be expected will not be complete if matter is atomic, because of atomic agitation. It may be assumed that the atoms themselves are made up of perfectly elastic bodies carrying electric charges, and the difficulty will thereby be turned. However, our knowledge of the nature of the atom is so incomplete that this is not much more than a subterfuge. It must be admitted that neither the classical nor relativistic theory gives any adequate account of the fine structure of matter.

Further measurement by means of light rays and Euclidean triangulation from any undisturbed reference body yields the position of other such bodies as if all these bodies were at rest in an augmented body or medium in which the rays of light occupied straight lines. Any point of this hypothetical body may be called a point of space, whether or not an actual material body exists there. If there is no such body the space is said to be empty at the point. There is sometimes a tendency to find a lack of reality in the idea of empty space. This is due to a vague appreciation of the fact that space like number is an abstraction, although both are extremely useful. The physical properties noted when a material body is brought to a point of empty space are entirely definite. If a lighted match is placed in empty space (*i.e.*, in a vacuum) its flame is quenched; if a small balloon full of air is placed therein it explodes.

It will be observed that the space which has been defined is the relative space about an undisturbed reference body. At this stage a difference of nomenclature between the classical and relativistic theories appears. Undisturbed bodies may be moving with respect to one another. In the relativistic theory the space defined by any one such body has precisely the same significance as any other, while in the classical theory a particular body is singled out as absolutely at rest, and is used to define an absolute space. Nevertheless, as far as the simple experimental methods used above are concerned, no difference will appear in the various spaces.

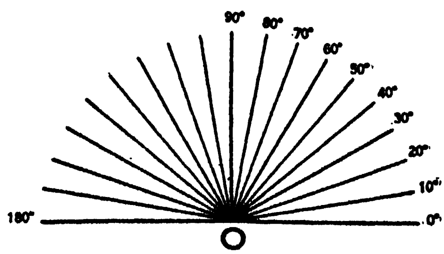
The laws of any such space have been stated to be Euclidean. It is distinctly worth while to pause and consider how simple and reasonable these laws are. The simplicity is often obscured by an effort at logical completeness, whereas if the logical demands imposed are only such as would have satisfied the early Greeks, geometrical laws are very easily understood.

Any (undisturbed) body is made up of parts. The smallest such part is indivisible and is called a point. The simplest body containing two distinct points is a straight line, an example of which is afforded by any ruler. Two such straight lines have the characteristic property that they will coincide throughout if they coincide in two distinct points. The plane is the simplest body containing three distinct points not in a straight line. Two planes will coincide throughout if they coincide in three points not in a straight line.

Plane geometry deals wholly with the relations of the parts in a plane. The facts concerning geometry in the plane (and indeed in space) can be taken to repose upon the following four assumptions.

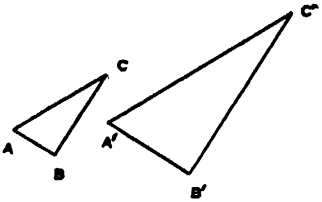
I. Measurement of distance in a line can be made by means of the ruler.

II. Measurement of the angle between lines can be made by means of the protractor.



III. One and only one straight line contains two given points.

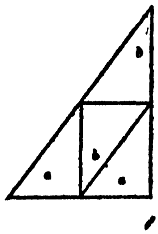
IV. The plane is alike and even similar to itself in all its parts. It is only as applied to triangles to the extent indicated in the adjoining figure that this assumption is required.



There are three propositions which follow readily from I–IV and are of central importance for the rest of geometry. We proceed to state and "prove" these briefly.

V. The sum of the two angles less than 90° in a right triangle is 90°.

The proof may be made as follows: Bisect the sides of the right triangle, by I. Join the three points of besection by three straight



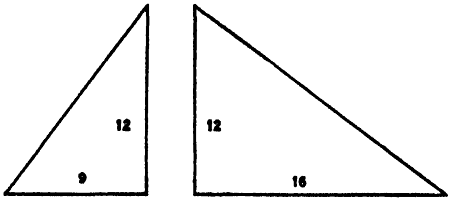
lines, as may be done by III. The three small triangles touching the three corners of the given right triangle are then clearly similar to that triangle in accordance with IV, with corresponding sides half as great. The same is seen to be true of the interior small triangle. Hence the angles labelled *a* and *b* are the same, and it is apparent that when these are added by means of the protractor in accordance with II, their sum is 90°.

VI. In a right triangle the side opposite the right angle is related always to the other two sides as in the case of the 3, 4, 5 triangle when

$$3^2 + 4^2 = 5^2, \text{ i.e., } 9 + 16 = 25.$$

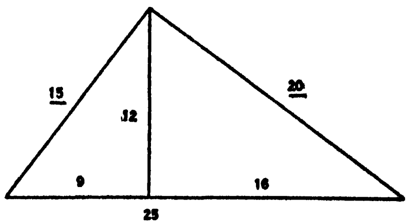
In the following discussion we shall show that a right triangle with sides adjacent to the right angle in the ratio 3 to 4, will have the side opposite that angle represented by 5. To prove it "in general" by the same method requires a little elementary algebra.

Consider the first triangle below in which the sides adjacent to the right angle are represented by 9 and 12 and therefore in the ratio 3 to 4. The numbers 9 and 12 are chosen instead of 3 and 4 to avoid fractions later.



This triangle, in which the remaining side is to be found, is clearly similar to the second right triangle with sides adjacent to the right angle in the ratio 12 to 16, as follows from IV.

If these two triangles be joined together so that the common sides coincide, a larger triangle is formed, of which the largest side

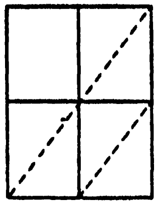


is $9 + 16$ or 25 by I. The opposite angle is the sum of the two angles which appear in each of the two component triangles. Hence this opposite angle is 90° by V, and the triangle formed by the combination is a right triangle also. The new right triangle thus obtained is similar to the previous ones, since its angles are the same.

We are now sufficiently advanced in our knowledge to find the magnitude of the required third side of the first triangle. If that side is 15, the side 9 of the first triangle will be in the same ratio to this unknown side as that side, taken as belonging to the combined triangle, bears to the side 25 in that triangle, for 9/15 and 15/25 are both 3/5. On the other hand, if that unknown side is more or less than 15, these ratios can not be equal since one will be less than 3/5 and the other greater. Thus the third side is exactly 15. The remaining side of the large triangle is of course 20. Hence it appears that if the sides adjacent to a right angle in a right triangle are represented by 3 and 4, the side opposite that angle is represented by 5.

The last proposition which we shall state is the following:

VII. Any two lines at right angles together with all the lines at right angles to them form a network of rectangles.



The truth of this statement is apparent from the same figure as we used in the proof of V.

It will be found that with the aid of the propositions I–VII it is a very easy matter to establish the main facts of elementary geometry which are really useful in its simplest applications.

The way in which many salient truths of geometry are incorporated in ordinary experience is astonishing. A host of relations between points, lines, planes, etc., are constantly apprehended at a single glance. Consider the obvious fact that if a man walks three miles east and then four miles north, he will arrive at the same destination as if he had first walked north four miles and then east three miles. This is a truth closely related to VII. There are many similar obvious facts embodying geometrical truths.

The preceding formulation of the methods and laws of spatial measurement indicates that there is no difference in the meaning of these for the old or new theory. The same is true of temporal measurement in its most fundamental aspect, as will be explained immediately. It is only in the interrelation of space and time that a difference will be found to exist.

Let a tuning fork be in an undisturbed state in the space which it defines, and afterwards let it be set in a state of slight vibration. Each point of the tuning fork will then execute a periodic vibration about a point of that space, and thereby give a means of measurement of the lapse of time, *i.e.*, a clock. This is a perfect clock for any theory yet considered, as far as indicating lapse of time is concerned. A clock may be defined to be any small mechanism which serves to indicate equal intervals of time in its history. Clocks are omnipresent in nature, and the vibrating atom of any element is a kind of ideal clock. A clock merely measures duration where it is, *i.e.*, local time.

The simplest method of comparing time at different places on an undisturbed reference body is by moving clocks very slowly from one place to another, so as not to interfere with their action. An alternative equivalent method available for a distant event is to take its time of happening as midway between the time of a light flash from the body reaching the point when the event happens and the time of the reflected flash returning to the body. By these

means simultaneity and time, as well as space, may be defined physically relative to the undisturbed reference body chosen.

It is to be especially observed that the actual physical means employed in constructing the system of space and time reference are identical in both theories.

In nature no completely undisturbed bodies are to be found, although some are nearly in such a state. Some such body of reference is used to set up a specific system of space and time. The query naturally arises as to whether it is not possible to define space and time otherwise than by means of small undisturbed reference bodies. The answer is that the corrections to the above processes then required are extremely technical. Consider a heavy elastic sphere at rest in the absolute space of the classical theory; a first requisite for its use in space measurement is a complete knowledge of the theories of elasticity and gravitation. In all cases and no matter which theory is adopted, the path to highly exact spatio-temporal measurement otherwise than as stated is an extremely arduous one.

There is a slight difference in the spatio-temporal facts as these are conceived in the two theories. In the classical theory there is a particular undisturbed reference body, absolutely at rest, for which the statement of physical law assumes a superior simplicity. For it, light travels with the same velocity in all directions, and the shape and size of other undisturbed bodies in relative motion, taken at an instant of its own absolute time, are the same as if the bodies were at rest. In the theory of relativity every undisturbed reference body defines a relative space and time which has the same validity as that of any other such body. To counterbalance this increase in simplicity, however, there will exist a modification in the shape and size of an undisturbed reference body in relative motion as obtained by the indirect optical method, although there will be no modification if the dimensions are determined by direct spatial measurement.

It is particularly important to understand the modification to which the notions of time and simultaneity are subjected in the passage from the old to the new ideas.

In whatever way time may be determined, there is one property unconditionally demanded, namely, that it be impossible to modify events subsequent to their happening. If a wireless signal is sent from Boston at exactly 12 o'clock, it must not affect the New York receiving station before that hour. Similarly, if a signal is sent from New York at 12 o'clock, it must not reach Boston before that hour. However, since the signal only takes about one five-hundredth of a second to pass back and forth, it is clear that this

single demand upon the notion of time has fixed simultaneity to within very narrow limits. Now there is no known velocity which exceeds that of light and electricity. In fact, such a velocity seems contrary to the essential constitution of nature. Hence this kind of simultaneity appears to admit of no clearer definition. It may be termed ordinary simultaneity.

Absolute simultaneity is of an entirely different character. It implies the existence of a uniquely defined system of time measurement, with the aid of which the statement of general physical law obtains its maximum simplicity. For example, the law of gravitation formulated by Newton for classical physics will only hold if absolute time is used in the measurement of the gravitational acceleration of bodies. Such is the absolute simultaneity of classical physics.

On the other hand, if some specific system of time measurement is taken which yields the maximum simplicity of physical laws, and yet there exist other systems for which the same laws hold, then there is no such thing as absolute time or absolute simultaneity. This is the situation in relativity where the various systems of time measurement for undisturbed reference bodies are equally valid.

Thus the absolute time and simultaneity of the classical physics are replaced by a relative time and simultaneity dependent on the undisturbed reference body selected. The new simultaneity meets the fundamental demand first imposed.

There is a third kind of simultaneity which may be called transcendental. If the mind of Deity envisaged events in a temporal order, there would be defined a transcendental type. Similarly, if telepathic communication became possible and was found to be instantaneous in the sense that immediate communication back and forth was possible, then a species of transcendental simultaneity would be thereby defined. The validity of any transcendental simultaneity is entirely speculative, of course.

Einstein was the first to realize that it is not necessary to hold to the notion of absolute time. While absolute space had not been securely defined in the Newtonian theory, absolute time and its attendant concept of absolute simultaneity had never been questioned before. The cornerstone of Einstein's logical analysis of space and time declares the abandonment of the unnecessary hypothesis of absolute time, at least until it is called for by the physical facts. This implies that the notion of a rigid body must be held in abeyance, too, since the rigid body is conceived of as one which can move about freely, while the distance between a pair of its points at any instant of absolute time remains invariable. Such a statement becomes meaningless when the notion of absolute time is abandoned.

It may ultimately appear that one particular reference space possesses an entirely superior character for the statement of the laws of nature, and hence we may wish to call that space absolute. Likewise some one time may be preferable, in which case it may be called absolute time. Nevertheless, even if this happens to be the case, it will be well not to forget that such a particular choice is in no sense *a priori*, but is a matter of convenience and is arrived at through observed laws experimentally determined. It will be seen that this broader point of view insists that the universe of events has primary significance, and that it is desirable to characterize it in some fashion or other in terms of a three-dimensional space and one-dimensional time, together constituting what may be called the four-dimensional space-time of events.

It is idealized interstellar space which furnishes the *motif* for the new physics much as the idealized rigid body did for the old. In interstellar space are found vast stretches of empty space with here and there comparatively infinitesimal stars, moving with velocities relative to one another which may reach hundreds of miles a second. From these bodies light spreads out with inconceivable exactitude in every direction, and may be measured by means of that eye of the astronomer, the telescope, and his clock. Thus we are striving to interpret anew this world of the astronomer.

In the new model there seems to be only one type of measurable quantity, namely, that of duration at any one of the particles by which we propose to replace the stars and other bodies in interstellar space, in order to idealize and simplify it to the utmost. We propose to assume also that this duration is measurable by means of clocks at the particles, and has physical significance in the correlation of events happening at the particle. These clocks are taken to be identical in structure, so that if they are brought together they will run at the same rate. Such clocks exist in any physical theory which has been so far proposed.

Other particles may be at rest relatively to a given particle, as will be evidenced when a light signal always takes the same time to travel back and forth in the time measured on the clock of the first particle. Three particles relatively at rest will furnish a basis triangle, by which a space of reference may be set up through a light-signaling process only. The experimental rules adopted in doing this will be exactly the same as for three particles at rest in the ether of the classical theory, so that a particular time of reference will be obtained also.

It can now be *proved* that if space-time is alike in all its parts (which seems as natural and inevitable an assumption as that the plane of Euclidean geometry is alike in all its parts) then the reference space and time will have notably simple properties.

In the first place any such space will be subject to exact Euclidean laws of distance, and the angles obtained by lightsignaling methods. Here we obtain an optical interpretation of space akin to that demanded by Aristotle. Bodies at each instant of the chosen time fill a part of this space. It is found, further, that light will travel with one constant velocity in all directions, and other particles will travel with uniform velocity in a straight line, that velocity being less than that of light. It will even appear that the relative velocities of two particles is the same in the system of reference of either.

All the assumptions hitherto used are granted either in the classical or relativistic theory, and so it would seem that there is no denying the correctness of the logical analysis of the model presented by interstellar space, as far as we have proceeded with it.

The characteristic hypothesis of the theory of relativity now enters. Up to this point there has been a perfect parity between all the particles in interstellar space, and as far as that model is concerned it seems as inevitable to assume that this parity is complete as it does to assume that all points are on a parity in the Euclidean plane. The hypothesis of relativity merely asserts the parity to be complete.

It is desirable to be more specific. If a particle B is moving relatively to the reference particle A, it is not hard to show that the apparent rate of B's clock measured in A's own reference space and time will vary in general with B's apparent velocity. It is necessary to emphasize the fact that the rate of B's clock so measured can not be in general the same as the rate of the clock at A even in the classical theory, since in that theory it will only be the same if the reference particle A happens to be absolutely at rest.

The characteristic assumption may now be stated in the more specific terms: The apparent rate of B's clock in A's space and time depends in exactly the same way on the relative velocity of B whatever particle A is.

It is even sufficient to demand that when direct visual observation of the rate of B's clock is made at A, its rate is the same as that of A's clock as observed visually at B, at least if A and B approach one another or recede in the same straight line.

When stated in this form the truth of relativity almost takes on a philosophic necessity. Imagine an interstellar space containing only two particles which are approaching each other. Why should not the relation between them be entirely symmetrical?

Now the space-time was highly idealized in that only point particles were assumed to be present. As a matter of fact such matter will always have spatial extension. If the spirit of the char-

acteristic hypothesis of relativity is to be maintained, it must be assumed that undisturbed elastic matter at rest in any reference space will always have the same size and shape, *i.e.*, that the back and forth signaling time between any pair of points of such a body will be the same under all circumstances. It follows that direct measurement by superposition of undisturbed elastic bodies may be employed. This substantiates more fully the claim made earlier concerning the rôle of geometry in relativity. Of course in actual experience the conditions are not met exactly, but the same difficulty is presented whatever theory is adopted.

A more careful examination of the consequences of the hypothesis of relativity shows that the respective times and spaces appertaining to any two reference bodies are the same if and only if they are relatively at rest. If they are moving slowly relatively to one another in comparison with the velocity of light, the differences between their respective spaces and times are extremely minute, and altogether beyond the range of observation under the conditions which usually obtain. Nevertheless, differences are found to exist, which justifies the caution which enjoined us from assuming an absolute time. It must be emphasized that the various spaces and times are effectively interrelated, so that time can no longer be thought of by itself.

It is unreasonable to expect any very obvious relation to exist between two different systems of space and time reference. Is it obvious how latitude and longitude on the earth would be modified if the magnetic pole were used instead of the north pole?

Thus the facts observed in everyday experience are as well accounted for by the theory of relativity as by the classical theory of space and time, while the former is superior in that it explains the futility of any experiment, like that of Michelson, designed to determine the absolute motion of any particle in interstellar space.

The theory outlined above is the special theory of relativity formulated by Einstein in 1905. The formulation took no account of gravitation, and yet it is possible to formulate a relativistic law of gravitation in harmony with that theory. Einstein's general theory of relativity of 1915 accounted for gravitation even more completely and profoundly.

It is often thought that there is something inconsistent about the special theory of Einstein. This is a mistaken point of view. In fact the theory of relativity, like Euclidean geometry, is a complete theory which may or may not be exactly applicable to the physical world in which we live. It is a self-consistent abstraction in any case, and the proof of its self-consistency is no more difficult

than that of elementary geometry. The self-consistency of geometry is usually assumed without question because geometrical relations are approximately realized in experience but that circumstance alone is not sufficient to make it rigorously self-consistent. Similarly, if we are willing to take the analysis of interstellar space (which certainly has physical existence) as proceeding intuitionally along the lines indicated above, we will not require a proof of self-consistency. If we refuse to accept this approach, an argument may be made of the purely arithmetic type available in geometry.

In our own world in which the relative velocities of bodies are very small when compared with that of light, nearly all the spaces and times are substantially identical. It may be conjectured that the laws of nature are such that, although relative velocities were high in the remote past, they have tended to diminish. Thus the low relative velocities now found may be accounted for. It is natural, notwithstanding, to look upon the situation just alluded to as an argument against relativity from the very standpoint of convenience so much insisted on hitherto, for it is certainly convenient to define some particular space and time with respect to which all the stars are in slow motion. The reply to this argument is merely that it is in no way indicated exactly what space and time are to be taken as absolute.

Thus the new point of view takes its start in the grandiose interstellar space of the astronomer, in which particles are in motion relative to one another, and light waves pass to and fro. The local clock and telescope are the only instruments of precision. If the parity of these particles be granted as a most reasonable hypothesis, the relativity of both space and time to the particular particle flows with the same inexorable necessity as prevails in the Euclidean geometry.

The situation is akin to that presented by the lines of symmetry in a closed oval. If the oval is circular, there are nfinitely many lines of symmetry passing through the center of the circle, and each is as valid as any other. The relativity of nature resides in a similar symmetry of natural law for various systems of spatio-temporal measurement. If a point on the circle is marked, there will be only one line of symmetry which will pass through the marked point. This is analogous to the fact that a specification of the reference body fixes the space and time completely.

THE JOSEPH LEIDY CENTENARY[1]

JOSEPH LEIDY'S INFLUENCE ON SCIENCE

By Dr. EDWARD S. MORSE
SALEM, MASSACHUSETTS

It was with some hesitation that I accepted the invitation of your committee to prepare an address on the subject of Joseph Leidy's influence on the science of his time. It is true that I am probably one of the oldest members of your academy, but it seemed to me that a member nearer home and consequently more intimate with Leidy's life and work would have been better chosen.

When Joseph Leidy began his studies there were only two centers of scientific study in this country, and these two centers were Philadelphia and Boston. In these two centers were established organizations that in a way paralleled each other. Philadelphia had its Academy of Natural Sciences and Boston had its Society of Natural History; Philadelphia had its American Philosophical Society and Boston had its American Academy of Arts and Sciences. The American Academy was organized in 1780, 37 years after the Philosophical Society, and both had among their members the immortal Philadelphian and Bostonian, Benjamin Franklin, who was the founder of the Philosophical Society.

In the transactions of these societies the memoirs and communications were of a similar nature. There were, it is true, isolated students of science in other parts of the country, but definite societies and museums there were few or none. In scientific work Philadelphia antedated Boston by nearly a century. The labors of those men, John and William Bartram, easily marked Philadelphia as the pioneer city in scientific work. Linnaeus corresponded with John Bartram and pronounced him the greatest modern botanist in the world. John Bartram is described by his son William as a man of modest and gentle manners, frank, quiet and of great good-nature. It would seem from this characterization that the mantle of John Bartram had descended on Joseph Leidy. It was in the territory about Philadelphia that the Bartrams had roamed and studied, and it was over this same region that Leidy found the material for his work in its woods, fields and ditches.

Leidy was a naturalist in the broadest sense and his scientific contributions to the number of hundreds embraced the wide field of comparative anatomy, zoology, botany, paleontology and mineralogy. In

[1] Papers read at the Academy of Natural Science of Philadelphia on December 6, 1923, to celebrate the centenary of the birth of Joseph Leidy.

the last century throughout the entire range of the animal and plant kingdom the country was rich in undescribed species. To the young naturalist the fascination of discovering and describing new species was overwhelming and some there are who have never outgrown this lust. What wonder that the zoologists and botanists of that era devoted their energies to the work of detecting and defining new forms. Agassiz used to say that the species described typified the mason who supplied the bricks for the edifice, an important work to be accomplished but followed by the same disaster if done improperly. With the growing scarcity of undescribed species the same kind of mental energy is now-a-days concentrated on defining new genera, and this tendency is becoming so accentuated that one may predict with certainty that ultimately every species will have its own generic name, and in print accompanied by an appalling synonymy. As the curious rules of nomenclature permit of more than one specific name we shall soon have—but enough of this.

Joseph Leidy, in the midst of this greed and rush for new species, steadily pursued his researches on the habits and anatomical details of creatures embracing the entire animal kingdom from the lowest rhizopod to the highest mammal. He described the new species and genera as they naturally revealed themselves in the course of his investigations, but this work was subsidiary to his greater studies. One stands amazed at the wide range of his observations. The diversity of his work began when he was comparatively a young man. Others will address you on this subject, but I can not refrain from calling your attention to the indices of the Proceedings of this Academy for the years of 1846, 1847 and 1848, to illustrate the breadth of his studies; he it was who determined that America was the ancestral home of the horse. His profound knowledge of the osteology of mammals enabled him to identify a fragment of a fossil tooth as belonging to a species of rhinoceros. Naturalists and paleontologists were skeptical as to the rhinoceros ever having lived in America, yet, later, in the same region in Nebraska, by a remarkable coincidence, the fossil skull of an unmistakable rhinoceros was exhumed and the remains of the very tooth was found embedded in its jaw.

That eminent zoologist, William K. Brooks, in a memoir on Leidy says, "He laid with the hands of a master the foundation for the paleontology of the reptiles and mammals of North America, and we know what a wonderful and instructive and world-renowned structure his successors have reared upon his foundation." Leidy's first communication to the Academy on Paleontology was in the year of 1848, and his last communication on the subject was in the year of 1888. Nearly a third of his memoirs to the number of 216 were devoted to this subject alone, absorbing nearly forty years of

his life. This task would have given him the world-wide reputation he sustained as a great naturalist, but at intervals during this prodigious work he found time to make investigations in many other and widely varied subjects in the animal and plant kingdoms, accompanied by innumerable drawings of the utmost delicacy and refinement. At a recent celebration, in Philadelphia, of the centenary of Louis Pasteur, Dr. Robert A. Hare, in a felicitous speech at the dinner given on that occasion, pointed out a number of striking parallelisms in the lives of Leidy and Pasteur. It was, indeed, a high honor to sustain resemblances to this immortal genius, and one who knows the history of these great men realizes the justice and accuracy of these comparisons.

Leidy's memoir entitled "Flora and fauna within living animals," accepted in 1851 by the Smithsonian Institution and published in its transactions, contains a long introductory chapter in which is discussed questions of the origin of life, spontaneous generation, years in advance of Pasteur and Darwin and anticipating many of their conclusions.

In an address given by Dr. Henry C. Chapman, at the unveiling of the statue of Leidy, in Philadelphia, in 1907, he quotes from a memoir by Leidy, in 1853, written six years before the appearance of Darwin's great work on the origin of species, and says. "Where, it may be asked, can there be found in the whole range of biological literature a more concise record of the origin of life, the extinction of species, the survival of the fittest, in a word, of Darwinism?"

I remember attending a stated meeting of this academy over fifty years ago. Leidy and other naturalists were present and the charming atmosphere and genial discussions reminded me of similar meetings of the Boston Society of Natural History at the same period: an identical group of kindly men, the amiable discussions without a tinge of acrimony remains a lasting impression. The days of Gilbert White have long since vanished. Have we also lost the stage typified by Leidy, Conrad, Lea, Haldeman, Meehan, Morton, Allen and others of like character? To a young collector of natural history objects it must have been an inspiration to attend these meetings and to realize that scholarly men were soberly discussing the habits of a common worm, or the structure of a beetle's leg. To see spectacled gentlemen seriously admiring little shells in a pasteboard tray, to appreciate how a well-written label added dignity to a trifle; to further realize that the little collection of natural history objects which they had brought together and for the collecting of which they had been laughed at or sneered at by unsympathetic neighbors were regarded by those men with interest and respect. Alas! these blissful days have passed. I know by my own

experience that the collectors' interests have vastly changed since those days. In the middle of the last century private collections of shells and other objects of natural history were not uncommon. The spirit of collection still survives, but other classes of objects claim its attention—postage stamps, coins, book-plates, etc., are deemed worthy of accumulation. The same tendencies are recognized in England. An eminent English authority in a report to the Liverpool Free Museum laments that "private collections are failing in Liverpool and all around, and teaching is hard and hardening in its results."

Leidy's profound range of knowledge, coupled with his willingness to answer inquiries, made him eagerly sought for, and crystals, precious stones, flowers, fossil forms and all kinds of animals were submitted to him for identification. It was the personal contact of a great master with students of every branch of natural history in which Leidy's influence on the science of his time exerted its greatest effect; questions answered, difficult attributions explained, obscure points made clear, all with a generosity of time, a kindliness of heart that left grateful and lasting impressions on the student. As a young man I marveled at the delicacy of his drawings, particularly his drawings made under the microscope, especially those depicting the anatomy of the terrestrial mollusks of the United States. He used a peculiar enameled paper, of which he gave me a number of sheets, and a metallic pencil. His gentle and cordial manner won my heart at once, and I went back home greatly encouraged in my studies by this simple interview. His broad and unprejudiced attitude was well shown in an incident which occurred at the meeting of the American Association for the Advancement of Science, at Troy, New York, in 1871. At this meeting I gave my views as to the systematic position of the brachiopods, endeavoring to show that these animals had no relation to the branch of mollusca with which they had always been associated, but that their affinities were with the class of worms. Leidy was at this meeting, but not a word in protest was expressed by him in contradicting these views; not that he agreed with me, for he did not, but, as I believe, from mere kindness of heart he refrained from combatting my heresies publicly. After the meeting, however, he came to me and quietly protested my views. I remember very clearly he urged me to save what little reputation I might have acquired as a student of mollusca by warning me to be sure of my ground before publishing. I confessed to him that perhaps I had not made myself clear in my extemporary remarks on the subject, but when he had seen my memoir with its illustrations and arguments it might possibly modify his views. Some months after in acknowledgment of my

pamphlet I got the following note from Leidy. "I have just finished reading the little book you so kindly sent me on the 'Systematic Position of the Brachiopods.' These, I think, you have clearly proved not to be true mollusks and to be more nearly related to the worms. It is singular how long mere outward resemblances deceive us and how reluctant we become to be undeceived."

Dr. Amos Binney, of Boston, published a work in three volumes on the "Terrestrial Air-breathing Mollusks of the United States." All the species then known were illustrated by steel engravings done by a Philadelphia artist. It was for this work that Dr. Leidy made a study of the anatomical structure of many species and the drawings illustrating these details for delicacy and beauty have never been equaled. Ten years before this work appeared Dr. S. Stehman Haldeman, a member of this academy, published a monograph of the "Air-breathing Fresh Water Mollusks of the United States," illustrated with colored steel engravings, so perfect that for accuracy and beauty they have never been surpassed. Of the 86 species figured half of them had been discovered and named by Thomas Say, a Philadelphian. Dr. Binney regarded Thomas Say as the earliest scientific naturalist that this country had produced. Dr. Binney was a Bostonian with all the proverbial pride of that city. He dedicated his great work in the following words:

> To the Academy of Natural Sciences of Philadelphia, to whose founders is due the first effective impulse given to the study of natural science of North America, and whose labors have been mainly instrumental in developing the natural history of this country.

It is interesting to note that Dr. Binney's son, William G. Binney, inherited the tastes of his father and continued his father's investigations with the greatest success; it is further interesting to observe that young Binney gravitated to Germantown, near Philadelphia, where he pursued his studies to the end of his life. Here he found as his associates, Lea, Conrad, Haldeman, Tryon and other distinguished students of mollusca, all members of this academy. Superadded to all these advantages he had access to the academy's collection of shells—one of the greatest in the world, and now in charge of Dr. Henry A. Pilsbry, one of our most distinguished malacologists.

In a preparation of this brief address it has been difficult to refrain from trenching on the grounds of others who honor us with their presence; in truth, the ground is broad enough for all, but it was necessary to understand the transcendent merits of this humane and world-famed naturalist in order to realize the profound influence he must have exerted on his colleagues in this center of scien-

tific culture. A standard was set by Leidy in every department of natural science and however feebly this standard may have been attained by some, an insensible pressure must have been continually exerted by the work of this great man in their midst. Philadelphia undoubtedly owes to-day its supremacy in natural science and the exalted character of its scientific institution to the work and example of this distinguished scholar.

LEIDY'S ZOOLOGICAL WORK

By Professor H. S. JENNINGS

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So many-sided was Leidy's work, even in the single field of zoology, that whoever examines it must be skeptical of the adequacy of his own impressions. And particularly will he be skeptical as to the adequacy of any brief unified presentation, such as it falls to my lot to attempt. The most I can hope is to illuminate a few of the many facets which his work presents.

Leidy seems to have attempted and carried out to a remarkable degree of success the bold project of forming for himself and communicating partly to others, a detailed picture of the entire living world in its natural relations to the environment. His zoological work is part of that effort. We find from him contributions on almost every one of the main groups of animals; and touching most aspects of their biology. The subjects of his published communications range from man and the other vertebrates down through the insects, arachnids, crustacea, annelids, rotifera, flatworms, nematodes, tapeworms, bryozoa, mollusca, echinoderms, coelenterates and sponges, to the lowest of the protozoa; and they deal with the structure, habits, reproduction, distribution and general biological relations of these creatures.

In his youth, we are told, Leidy's aptitudes were such that his father designed him for the career of an artist (though this design was overruled by the family court of last resort). In this fact lies, I believe, the key to an understanding of many features of his work in science. His work is largely a *portrayal* of nature as seen by a thorough scientific artist. It is artistic in spirit, not merely superficially, in the beautiful figures with which he illustrated it, but in its essential nature. His manifold contributions, of which between 500 and 600 are listed, may be compared to the studies from nature by a painter, ranging from the quick sketches in a few strokes, represented by his hundreds of brief communications to the *Proceedings* of the Academy of Natural Sciences of Phila-

delphia, through pictures of all grades of working out, up to such great and finished masterpieces as the volume on the "Fresh Water Rhizopods." All are mainly pictures of nature, not analytical treatises. To him biology was not, as it now is to so many, so much a series of problems to be solved as it was a continent to be explored, a landscape to be portrayed. There is little of experimental or statistical or conceptual analysis in his work; it contains few hypotheses or generalizations. Where such are mentioned, they are not as a rule looked upon as part of the material for investigation; not as matters to be tested by analysis of his data; he rarely draws from his observations conclusions concerning them. His work is a portrayal of nature as he saw it, and no one else in America has made for himself so uniformly worked out a picture of the world of organisms.

Now, of course, this means a scientific picture, with all that that implies of minute study of details, and of portrayal of these details in correct relations; his work was as far as possible from impressionistic. And the comparison with the work of the artist must of course not be pressed too far. Leidy had, too, the instincts and the capabilities of the analyst, the experimenter, the generalizer. In some of his earliest work, as we shall see, the products of those instincts are conspicuous; but in his later zoological work they are largely absent; and for a brief characterization, that as the scientific artist of nature is, on the whole, one that helps.

For his completer pictures in zoology he chose those groups of organisms which came naturally to hand. Living in Philadelphia, these were chiefly the inhabitants of the fresh-water ponds and streams. Contributions there are, and important ones, on the invertebrates of the land, of the air and of the seashore; on parasitic organisms and on marine animals; but of life in the fresh waters his pictures are most numerous and detailed.

Outside of that field, however, lie his first really worked out pictures, the paper on the parasites of the termites, and that on "A Flora and Fauna within Living Animals," published in 1853. Both are captivating examples of zoological landscape painting, illustrated with the beautiful figures so characteristic of Leidy. But it is in the latter paper that the young author shows his natural bent toward experimentation and toward generalization. In an introductory section on the "laws of life in general," he mentions experiments which he had carried out on spontaneous generation; on endosmosis, and on the effects of ingesting infusoria and bacteria. In the latter he tried on himself the somewhat hazardous experiment of swallowing water containing, as he says "*Monas, Vibrio, Euglena, Volvox, Leucophrys, Paramecium, Vorticella,*

etc.," but with no detectable consequences. It was in this paper, too, that he gave, six years before the publication of Darwin's *Origin of Species,* his famous statement of the doctrine of evolution, of his belief in the origin of the organic from the inorganic and of the general course which he conceived the development of the animal world to have followed. This striking statement should perhaps be quoted in any general characterization of Leidy's zoological work. He says:

> An attentive study of geology proves that there was a time when no living bodies existed on the earth. . . . Living beings, characterized by a peculiar structure and series of phenomena, appeared upon earth at a definite though very remote period. Composed of the same ultimate elements which constitute the earth, they originated in the pre-existing materials of their structure. . . . The study of the earth's crust teaches us tha very many species of plants and animals became extinct at successive periods, while other races originated to occupy their places. This probably was the result in many cases of a change in exterior conditions incompatible with the life of a certain species, and favorable to the primitive production of others. . . . Probably every species has a definite course to run in consequence of a general law; an origin, an increase, a point of culmination, a decline and an extinction.

Such statements, made in 1853, bring again to realization what we sometimes forget, that what Darwin did was not to propound a new idea, but to give overwhelming evidence in favor of a theory that was familiar to all intelligent students and that was held by many of them. In his later works Leidy largely restrained himself from any tendency to generalize; one wonders whether from conscious principle, as from something cheap and easy. Experimentation also becomes infrequent, though it does occur. One suspects that if Leidy had lived in the period when biology became more analytical, he might have become another Driesch or Morgan.

Other detailed portrayals of nature are found in his work on the anatomy of the terrestrial gastropods, in Binney's *Terrestrial Mollusca*; and in his papers on *Urnatella,* on *Belostoma,* on the walking-stick, on *Corydalus,* on marine sponges.

But for zoologists his great masterpiece is the volume "The Fresh-Water Rhizopods of North America"; some consideration of this will bring out the characteristics of his zoological work. In general, scientific books and papers are among the most evanescent products of human activity. The advance of knowledge soon renders them out of date; they continue to live only in that they have supplied nutrition to their successors. But such a work as Leidy's "Rhizopods" brings to realization the fact that perhaps the most permanent form of scientific literature lies in a full and accurate portrayal of some part of nature, without analyses of problematical matters, without hypotheses or generalizations. Generalizations

soon become inadequate; experimental and statistical analyses are superseded or become useless when once the conclusions on which they bear have been established or disproved. But an adequate account of a group of organisms in its relations to the rest of nature is like an adequate description of anatomy, or like the working-out of some of the constants of nature, like the computation of a table of logarithms—of each of these we can say that when 'tis done 'tis *done;* it need not be done again. This seems the case with Leidy's "Rhizopods"; it is a section of nature permanently preserved to us. From the first it was, and it will remain, a delightful guide to acquaintance with these strange and beautiful creatures, which sum up in miniature the riddles of life. The student with a microscope, a pond and Leidy's "Rhizopods" need envy the pleasures of no man in the world. And thousands of students have been in this happy situation; no other influence has been so potent in promoting acquaintance with the natural history of these lowest of animals. Even without the pond and the microscope, the volume is, for its illustrations, a delight to the artistic eye. But much more than all this; although zoology has become more analytical since Leidy, such a portrayal of nature is not left behind; it becomes only the more valuable. It presents to us with direct vividness the problems which nature sets, and it becomes a quarry of materials for work on those problems. The fundamental questions of biology—the problems of metabolism, of movement and behavior, of development, of reproduction, of heredity—come sharply to a point on the activities of the protoplasmic substance; here many students are directing their efforts. But conclusions in general biology and general physiology are often vitiated by the narrowness of the base on which they rest. A phenomenon is studied minutely in some one organism, and the conclusions drawable are held to be general laws of nature; whereas they are often but special peculiarities of that particular creature. Nowhere is this common error more easily fallen into than in connection with the lowest organisms, as I know to my cost.

Protoplasmic movement, for example, is indeed shown in *Amoeba* of the *proteus* type; and here zoologists usually study it and draw conclusions concerning it. But Leidy will show it to you occurring in many other naked protoplasmic masses differing greatly from Amoeba proteus; in Amoebae with tough skins, almost unchanging forms and rolling motion; in *Dinamoeba,* with its seemingly permanent outer layer studded with projecting points; in the gossamer-like branching and net-forming *Biomyxa vagans,* which compared to Amoeba proteus seems almost as simple as does *Amoeba proteus* compared to an insect. I still recall the feeling of

awe which this organism gave me the only time my microscope came across it, while following Leidy as a guide. *Amoeba proteus* when adequately studied doubtless does contain the secret of protoplasmic motion, just as the flower in the crannied wall contains all the secrets of God and man. But its outward manifestations of that motion may be gross and specialized peculiarities; I personally believe that they are. The student of that subject could not do better than take Leidy as his guide; study minutely protoplasmic motion in the extremely diverse types which he presents; in the various species fitted for the study of special points. Only so is there a chance to distinguish special peculiarities from general laws of protoplasmic movement.

This is typical of the situation with respect to other biological questions; with respect to nutritional problems, to the conditions of existence, to developmental and genetic problems. The student who tries to keep alive and to cultivate the various creatures of Leidy's pages finds the different ones so narrowly dependent upon particular nutritional conditions, and on other conditions that he becomes skeptical of general nutritional laws based upon the study of one or two kinds of animals. In relation to genetic processes and problems, Leidy's work is particularly alive and suggestive. He presents us in unrivaled figures and descriptions a vast assortment of different forms, exemplifying every degree of diversity. He classifies these, he distinguishes individual differences, varieties, species, genera, families, orders. What do these things mean genetically? Leidy tells us that in these creatures he believes that "no absolute distinctions of species and genera exist": that he finds the species "by intermediate forms or varieties merging into one another." In his accounts of particular species, he often emphasizes that they do thus merge by intermediate forms into others: also that within the single species or variety there are great variations of structure. What is the observational or experimental content, potential or actual, of these propositions? Does the "merging into one another" of two species mean that the individuals of one may and do produce at reproduction individuals of the other? If not, what does it mean? Are the individual diversities, are the so-called different varieties, to be found among the descendants of a single individual? Or are such diversities hereditary; permanent throughout the generations? Or may there be a process of gradual change, so that only after many generations may one variety be obtained from the other; or only after many generations may one break into several? What part does the environment play in all this?

These questions press upon us in studying Leidy, as they do when we study nature, but, like nature, he gives us no answers to

them. All may be attacked by simple and direct methods, and positive answers may be obtained; for most of the questions long periods of time are not required. The animals must be dealt with individually, cultivated individually, their pedigrees kept from generation to generation, as we do with rats; they must be handled as we handle rabbits. This can be done—it has been done for a few of Leidy's organisms—but only sufficiently to open up a vista of vast extent for future work. Some of the individual diversities within a species, it is found, have no hereditary basis—a parent of one type produces offspring of another—the environment may play a large part in determining which shall occur. But this is held between definite limits; and other individual diversities within a species *are* permanent and handed on from generation to generation. Each species contains numerous slightly but permanently differing strains. The so-called varieties do not produce one the other, and individuals of one so-called species do not produce individuals of the other. The merging into one another of which Leidy speaks is therefore not an experimental, a genetic, concept. Yet by long continued breeding for many generations, single strains are seen to gradually differentiate into slightly diverse ones, strains whose diversities are thereafter inherited from generation to generation. How far may this go? We do not know; as yet one "species" of the systematist has not been produced from another; nor even perhaps one "good" variety. I fear that we are still in the situation which Leidy summarized in 1853 when he said that "No one has ever been able to demonstrate the transmutation of one species into another"—even for species which he described as merging into one another.

Such work and other work must be carried out and greatly extended for all the different types which he describes. Their different methods of reproduction must be determined; we know almost nothing of their sexual processes or in most cases whether such exist. The nature and results of their seemingly inchoate, imperfect form of conjugation must be discovered; the details of their cytological processes worked out. Until all these are carried out to some level of attainment, the significance of the observations along the other lines must remain uncertain. For all this research, Leidy's work is a mine of suggestions and an indispensable guide. Many other of Leidy's contributions are similarly basic and suggestive.

But these examples must serve for many. In the brief time available I have attempted only to emphasize and illustrate the vitality of such work as Leidy's. In spite of the fact that it does little in the way of analysis and generalization, that it answers few general questions—perhaps indeed in virtue of that fact—it partakes somewhat of the inexhaustibleness of nature.

LEIDY'S PALEONTOLOGICAL AND GEOLOGICAL WORK

By Professor WILLIAM B. SCOTT
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Before I begin what I have to say on the subject of Leidy's work as a paleontologist, I think you would be interested to hear a letter, or at least a part of it, which I received some weeks ago from Sir Archibald Geikie, secretary of the Geological Society of London, and for many years director of the Geological Survey of Great Britain. In asking me to represent the Geological Society of London, of which I have the honor to be a member, he wrote this note.

> On the part of the Geological Society I am desired to inform you that we have been invited to send a delegate to the meetings that are to be held in connection with the commemoration of the centenary of Joseph Leidy, by the Academy of Natural Sciences of Philadelphia in December next. As foreign secretary I am desired to write you and express the hope that you will honour us by being our representative at the Joseph Leidy Celebration.
>
> The writing of this letter reminds me of my close intimacy with Joseph Leidy and the many friendly letters that passed between us. Should there be any representative of his family at the celebration in December, would you tell them how cordially I join in doing honor to the memory of one whom I reverenced and loved?
>
> With best wishes for your health,
>
> Very truly yours,
> Archibald Geikie

I may be pardoned, I hope, for continuing a moment or two on the personal note which this letter strikes. Osborn and I, in our senior year at Princeton—I ought to call him Professor Osborn, I suppose, but it is difficult to speak respectfully of one's classmates—you see, we know them too well—spent a large part of that year getting ready for the first of the expeditions to the Far West, as our hope was to get into the Fort Bridger country of Southern Wyoming. That immediately brought us into a study of Leidy's great monograph, published a little while before by the Hayden Survey, into attempting to learn what we were going to find in that country, and that went further to personal communication with Dr. Leidy. And after we had been in the Fort Bridger country in the summer of 1877 and made a large collection there, we spent a large part of our graduate year—1877 to 1878—in working up that collection, and we were constantly running to Philadelphia, and to the Academy, to see Leidy's types, to compare our material with that which he had described and named, and to ask his advice and his help. And though we were mere tyros, beginners, utterly in-

significant, he was invariably as kind and considerate and thoughtful and as lavish in the gift of his time as though he had had nothing else to do. I look back to those early years, when I began my professional career after having been in England and in Germany and had come back to resume my work at Princeton—I was constantly coming to see him, constantly referring problems to him for his consideration. Always, invariably, I got the help I wanted, and it was in such a contrast with the attitude of mind of many other distinguished men of science of that day. They were very "standoffish," many of them—they held you at arm's length and would tell you just as little as they could. I remember asking one very prominent paleontologist whether there were good collecting grounds at a certain region in Kansas. "Well," he said, "there were before I got there." That was all the satisfaction I could get out of him. Leidy wasn't a bit like that. What he had was yours if you asked him for it. And he had that sweetness and gentleness of personality that is so attractive when united with greatness. I have known a few great men in my life and, without exception, they have been men of extraordinary simplicity, without any airs, or graces—without any "side," as our English cousins put it. Huxley was another like that, only, living in London, he had to protect himself more than Leidy did here, because if he hadn't put a fence between himself and the public, he would have had no time for his work.

That is the note I want to leave with you, namely, that of extreme simplicity of character, of kindliness, of helpfulness, of feeling that his time belonged to any one who asked for it, if the object of that asking were not mere frivolity, but honest work.

Now it is a curious thing that both in Great Britain and in the United States the medical profession was until well into the nineteenth century—in fact the latter third of it—the only doorway to the study of zoology and paleontology. In England, the two greatest names in vertebrate paleontology that immediately stand out to any one who knows anything of the subject are Owen and Huxley. Both of them studied medicine. Huxley began his career as a ship surgeon and made a long voyage in a naval vessel which was as significant for his future as was the voyage of Darwin. The observations that he made on that voyage made a zoologist of him. Also, he did high class paleontological work.

Owen did perhaps more than any other man who ever wrote English in the volume and variety of the work which he published in vertebrate paleontology. He, too, began as a student of medicine, and his father-in-law, Dr. Cliffe, induced him to take the curatorship of the Museum of the Royal College of Surgeons in

London, from which he gained that amazing knowledge of comparative anatomy which made him a natural student of paleontology. The treasures which began to pour into England during the middle of the nineteenth century, from various exploring expeditions, were collected not only in Great Britain but throughout the world, and sent to Owen for description. The same thing was true in this country. All our early paleontologists were medical men, and it is therefore no mere coincidence that the center of paleontological work in this country, other than that of shells—invertebrate animals—was in Philadelphia. The first of them was Dr. Wistar—Caspar Wistar, whose name is held in such well-deserved reverence in this city yet, and the Wistar Institute is named for him.

Then there was Dr. Harlan; then came Leidy. Over in New York the same thing was true. The two naturalists who were most prominent in New York were Dr. Samuel L. Mitchill, a most extraordinary all-round person, and, I may say, because I am connected with his family, perhaps the most conceited man in the North American continent. He translated the "Theory of the Earth," and he said he did it at the request of President Jefferson who, he says, "remarked to me on one occasion that I was the only man in the country able to do it"—and he didn't add anything to that. He thought it was enough. "But," he thought, "I agree with Jefferson."

Samuel Mitchill was senator from New York and also was a very distinguished physician and also one of the earliest of New York naturalists, in the description not only of fossils but also of the living fauna of the state.

Dr. James deKay—I hope he didn't pronounce his name the way it is spelt—I wrote just the other day—(I see I can't get this off as my own, because the gentleman who gave me the facts is present in the audience; he is Dr. John M. Clark, the very distinguished superintendent of the Geological Survey of New York and the State Museum)—I wrote him the other day and asked him a simple question and he just showered information on me—namely, that deKay, who had charge of the botany and the zoology of the great New York Survey, was also a physician and deKay was one of the first men, I think, who ever described an American fossil horse. Thus, naturally enough, Leidy fell into the tradition because his tastes were that way, his interests were that way; as early as 1833 Sir Charles Lyell, the founder of modern geology, was in this city and he visited Leidy and told him: "Stick to paleontology. Don't bother with medicine. Stick to paleontology. That is your future." Well, Leidy didn't take his advice. In fact, under the conditions of those days it wouldn't have been feasible for him to

do so, because, like most of us, he had his living to make, and it could not have been made in those days by paleontological work.

Throughout his life, Leidy primarily was interested in human anatomy and he remained, almost to his death, professor of human anatomy in the Medical School of the University of Pennsylvania, but he felt always that man was only one of the vast multitude of animated beings. He told me once, laughing in that gentle way of his, of a student who came to him after a lecture and said, "Now, you don't really mean, professor, that man is an animal?" and Leidy answered, "Do you think he is a vegetable?" He, therefore, extended his work, as we have been told this morning, in all possible directions. Everything that lived had a fascination for him, and he wanted to learn not only its exterior appearance, and its habits, but he wished to know its structure, and in this way, quite unintentionally, he fitted himself to become the pioneer of vertebrate paleontology, which he was.

Now I could, of course, go on for a week, if necessary, if you just had the courage and patience to stay and listen, telling you a lot of technical details, but I have not the slightest idea of doing anything of the sort. It is Leidy's early history that I want to point out to you, and I think this audience, which is not composed of paleontologists entirely, is more interested in the influence which Leidy had in the development of this subject in which America has become supreme, especially in the vertebrates, throughout the world. All such things have their explanation and the reason of American supremacy in vertebrate paleontology is because of the vast material which this continent possesses. My friend Osborn has been lately getting over into Asia and finding equally great treasures there, and the expeditions which have just come back from China have brought us incredible and delightful treasures. Some of you heard of them in the newspapers. They have found dinosaur eggs. I hope the museum won't make any attempt to incubate those eggs, for it would be a misfortune to have dinosaurs on earth again. We are well rid of them.

Leidy's first publications in vertebrate paleontology dealt with certain bones found in a cave near Natchez, Mississippi. It was thought at first that these were human bones, because in those days and for a long time afterward every bone was human. There was a man who went through the southwest with a mastodon skeleton that he had mounted like a man, on two legs. The top of the skull was gone, so he restored the skull with a piece of rawhide like a human skull and exhibited it from town to town as the skeleton of a giant. And he had a trunk full of certificates from doctors in good practice that those were human bones.

These bones that were found in the cave were sent to Leidy, and they turned out to be bones of a curious ground-sloth, and it is interesting to note that it was on the ground-sloth that American paleontology began. The animal was described and named by Thomas Jefferson in 1805, or, that is, the volume of the Philosophical Society's Transactions appeared in that year—the paper, I think, was written about 1797, and in it he stated that the clawbone of a gigantic sloth was that of a gigantic lion. It wasn't much of a blunder. The resemblance is quite close, and Jefferson, of course, was an amateur. He didn't pretend to be anything else, but it is a paper that is full of interest from many points of view. I am sorry that my time does not permit me to tell you something about it.

Then the giant ox tribe attracted Leidy's attention, and he published a monograph on that. He published a monograph on the peccaries that were found in various parts of the country. Now, they are never found north of Texas.

Those surface things naturally came to him, but the fossils upon which his greatest reputation rests, I think, are the materials found in the Tertiary deposits of the Far West, notably in those beds which we have come to call the White River formation of Nebraska, because in those days Nebraska occupied all that northwest territory, including the present Dakotas and Kansas. It was a general term for that uninhabited region.

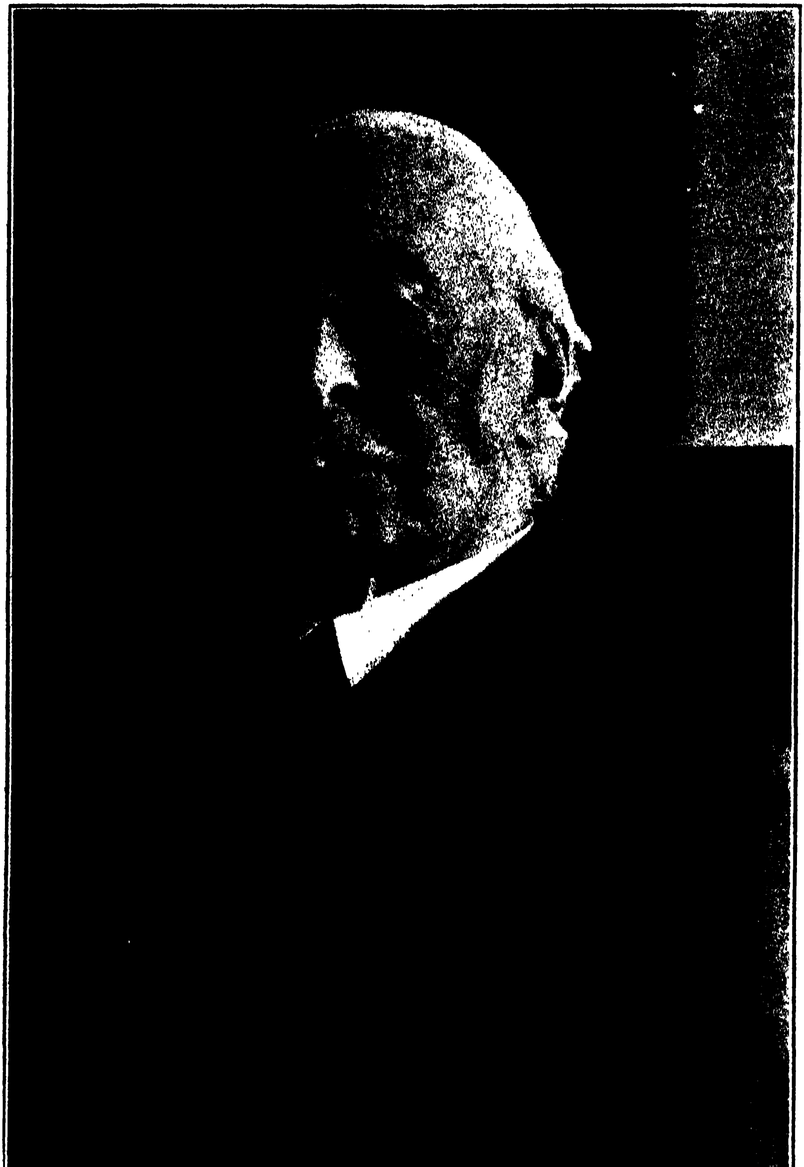
In the year 1849, I think it was, Dr. John Evans found some White River specimens and sent them to Dr. Leidy, and in the following year, an undergraduate of Princeton, Thaddeus Culbertson, who was afflicted with tuberculosis, had been ordered to go west by his physician, and he was advised by Professor Baird, who was then assistant secretary of the Smithsonian Institute, to this effect: "Go to the White River country and collect fossils and send them to Leidy, because Leidy is the only person in the country capable of dealing with them." Leidy published a number of papers on these fossils and then, in the year 1853, he gathered them together in one report, illustrated with the most beautiful lithographic plates I think that have ever been issued in any publication in America. They were made by a Swiss artist, Sonrel, and they are unrivaled in their beauty of execution. Still more comprehensive was the great work published by the academy here in the year 1869, and those works form the starting point, really, of our knowledge of the White River fauna, and we have been collecting there ever since. Expeditions go into the White River country every season, I think, but we have done very little except to fill in the sketch which Leidy outlined.

He was the first man to show, for instance, not only that there were native horses in America, and, as we were told this morning, the first American rhinoceroses. He found also the first of American camels, and it was shown that the line of the camels began here in America.

My time is running out and I want to say just one or two more words. Next followed his work on the Bridger formation, the older beds of southwest Wyoming, and in the year 1877 he made his first visit to those Bad Lands and wrote a most vivid description of the Bridger Basin. It shows what a geologist was lost in him, if he had had the opportunity to turn to that kind of work. He then published the first of the works on Upper Cretaceous reptiles in Montana and the Upper Cretaceous fauna of the Atlantic Coast. There is mounted in the museum of this academy the first dinosaur skeleton that was ever put together in America. There is a lot of conjectural restoration and the head—in fact, as put up by the late Waterhouse Hawkins, an English scientific man, not so very scientific, but known more for being artistic—the head is entirely grotesque, but it is the first time an attempt to put a dinosaur together was ever made and it is Leidy's dinosaur, described and named by him, from the Cretaceous of New Jersey. So, you see, he laid broad and deep the foundation upon which the great structure of American vertebrate paleontology has been erected. Why did he get out of it? There were two different reasons. They were both true, and one of them he didn't care to speak about much in public. Those of us whose hairs are gray or whose heads are devoid of hair will remember the bitter quarrel that existed—a feud—between Professor Marsh and Professor Cope. They succeeded Leidy to a certain extent and they hated one another with the most deadly hatred. Both were rich men, and so they diverted the stream of fossils from Leidy. As Leidy told Geike, he said, "I have got to get out because when anybody used to find a fossil they used to send it to me and I got it for nothing. Now to-day Cope and Marsh pay money for such things and I can't compete with their long purses and so I have got to get out." That is true enough. That is one reason. There was another reason which I don't think he ever expressed in public, but he did express it to me, and I have no doubt to many other people. He said, "I can't stand this fighting. It disgusts me and I am going to drop Paleontology and have nothing more to do with it because of the way Marsh and Cope are in each other's wool all the time." And yet he couldn't stop. And some of the last work of his life was done in describing not only the fossils from the phosphate beds of South Carolina, but later still the work

which he did in Florida. And it is a very interesting coincidence that one of the first things he described from the White River bed of Nebraska was the saber-toothed cat, tiger as we call him, which was about two feet high, and one of the last things he did before his death was to describe the termination of that tiger in the great beast it became in the Pliocene.

Now this is a most inadequate sketch of a vast subject, but you will easily see that you can not put a quart in a pint pot, and you can't describe a great character in fifteen minutes, but I hope I have left with you the impression that Leidy's work is the foundation upon which all subsequent American vertebrate paleontology was built.



—*Wide World Photos*

DR. CHARLES W. ELIOT

President emeritus of Harvard University, whose ninetieth birthday was celebrated on March 20 under the auspices of the Harvard Alumni Association, the Associated Harvard Clubs and an honorary committee of citizens, of which President Coolidge is chairman.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

CHEMICAL MESSENGERS

What system of government prevails in this body of ours? Is it an autocracy, the one-man rule, such as prevailed in the primitive state and still survives in the army? Or is it a democracy, the equal power of all in politics, regardless of their qualifications, such as is now regarded as the ideal? Or is it an oligarchy where the superior cells and organs manage the inferior?

Strange to say, no system of human government has yet been devised that approaches the organization of the animal organism in character—or in success. The millions of cells, the hundreds of muscles, the dozens of organs, with their infinitely varied powers and functions, are kept in harmonious activity for the good of the whole by some secret system of mutual cooperation which man has not yet learned how to apply to his artificial organism, the state.

The conscious ego can not claim to be the dictator of the physiological realm which he calls his body. He is not even a premier, but merely a foreign minister. He has a certain control over imports and exports, but the department of the interior is mostly beyond his jurisdiction. It is his business to keep the body out of fights with others that might result in a stab in the heart or a punch in the stomach, but he is not entrusted with such essential functions as keeping the heart pumping and the stomach digesting. For, important as the mind may think itself, it sleeps at its post for a third of the twenty-four hours and is liable to occasional fits of forgetfulness at any time. It is not the brain that mobilizes the white blood corpuscles whenever an army of microbes invades the body through a breach in the outer wall. Sight is not sharp enough to see a microbe, and even if the brain suspected an invasion it would not know how to conscript the corpuscles and dispatch them to the front.

All these millions of living cells in brain or brawn or bone have to be kept supplied with food, water and air, in amount depending on how they are working and how fast they are growing. The temperature of every part of the body has to be kept constant no matter whether the weather is cold or warm, and the ashes must not be allowed to accumulate in any cell.

Now one would think that such a marvelously complicated coordination of interdependent activities would require a strict system of bureaucratic centralized government. But, on the contrary, the central government, if there is such, has little or nothing to say about most of the physiological processes. The orders to an organ come from below rather than above. For instance, if an over-worked muscle needs more oxygen, it does not petition headquarters, but sends orders direct to the heart and lungs to speed up the pumping. If a gang of structural bone workers want more lime or phosphate they do not bother the boss about it, but dispatch a message straight to the supply department to import some.

How these multifarious messages could be carried was long a mystery, but is now being solved. There are two ways of intercommunication in the body just as there are in the outside world, telegraph and mail. In a

telegraphed message nothing travels except the electrical impulse, but in the postal service a material message, the letter, is transmitted. Inside the body signals may be sent by the nerves, which play the part of telegraph wires, but it has recently been discovered that there is another and more general system of intercommunication by means of chemical substances sent around through the blood, like letters. Professor E. H. Starling, of London, pointed out the importance of these eighteen years ago and named them "hormones," which is Greek for "messengers," and since then many of them have been discovered and some of them manufactured.

The two systems of transmitting orders supplement each other like telegraph and mail. For instance, a man sits down at a dinner table. The eye signals by way of the nerves, "I see food," and a minute later comes confirmation from the nose, "I smell it." At once the saliva begins to pour into the mouth and the gastric juice into the stomach to prepare for the first stages of digestion.

Sometime later when the stomach has finished its work, three other digestive fluids have to be in readiness. These are secreted by three separate organs, the pancreas, the liver and the intestinal glands, and all these have to be notified to get busy as soon as the first food passes out of the stomach.

In this case the message is conveyed by a hormone called "secretin" which within two minutes after it has been sent into the blood stream sets the three organs to preparing their particular digestive juices.

If we get angry or scared, the body has to be put into a state of preparedness for fight or flight, whichever the high authority decides upon. But either will require an extra supply of energy, so the suprarenal glands, without waiting for special orders from headquarters, send a chemical messenger to the heart to pump harder and to the liver to release more sugar into the blood so that no muscle shall be short of fuel in this emergency.

How the sugar is handled depends on another hormone known as "insulin" which has lately been prepared in a form that may be used by diabetics whose pancreas does not work well.

Still more recently comes the announcement of the extraction of a pure and extremely powerful form of "pituitrin," the secretion of the insignificant pituitary body, that controls the kidneys and capillaries.

The chemist is now able to make "thyroxin," which is secreted by the thyroid glands, and a minute daily dose of this may, as Dr. Starling says, effect "the conversion of a stunted, pot-bellied, slavering cretin into a pretty, attractive child."

It is these chemical messengers which in infinitesimal amounts determine whether we shall be tall or short, dark or fair, handsome or ugly, active or sluggish, alert or stupid, cheerful or melancholy, and it is the aim of the chemist to learn how to make them, or perhaps similar substances of even greater potency so that he can acquire absolute control over the workings of the human body.

THE USE AND MISUSE OF EDUCATION

Learning is a tool. Its value depends on what is done with it. Give a jack-knife to a boy and he may whittle wood or cut his fingers with it. The knife is neutral. Much of elementary education must be merely formal, the giving of tools to children. The three R's are nothing in themselves. They are merely the keys to the knowledge of good and evil. Whether they prove beneficial

or injurious to the student depends on what use he makes of them. Reading the wrong books may make a man worse than an ignoramus. Learning writing may qualify him for forgery and learning arithmetic for swindling. The value of a ship's load can not be calculated by the inspection of the Plimsoll mark. The value of an education depends more on the character of the cargo than on the capacity of the cranium that carries it. Neither an information test nor an intelligence test can determine what the man's mind will be worth to the world.

In repeating these hackneyed observations, I am not presenting an argument against the alphabet, but I am pleading for its proper employment. Illiteracy is always a bad thing, but literacy may be an evil thing.

Opportunity does not insure progress. Christian missionaries like Livingstone rejoiced over the opening up of Africa by commerce and communications because they naturally and naïvely assumed that it meant the spread of Christianity. On the contrary, it led to an unprecedented spread of Mohammedanism, their most formidable foe.

If science teachers merely teach their students to use the appliances of science and fail to train them in the scientific way of thinking they may find the intellectual aims of science defeated by the machinery of science. The printing press contributes to the spread of superstition and obscurantism as well as to the spread of science. The newspapers publish a lesson in astrology more often than a lesson in astronomy. In our books and magazines fiction vastly outweighs fact. By means of the radio Voliva's argument for a flat earth is broadcasted from Zion City all round the world.

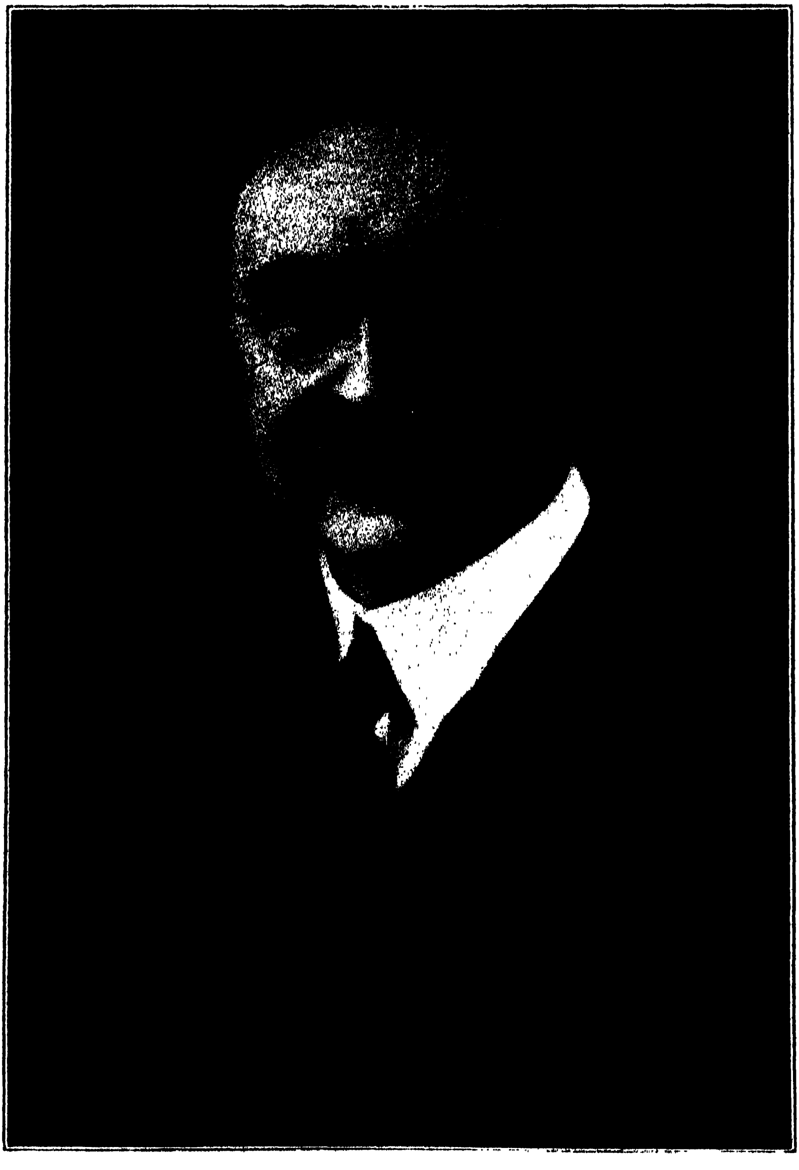
The main object of education in a democracy is not to teach the students how to vote right, but to train them how to think right. Under any form of government, in an autocracy no less than in a democracy, the real power lies in the people, and it is their individual every-day conduct, guided by their personal beliefs, that determines whether the nation shall advance, stagnate or retrograde.

Politics is not yet a science and there are many ways of reaching the same result. In science there is only one truth but an infinitude of falsehoods. A problem has a single solution. An unwise popular vote on a political question may bring a temporary calamity upon a nation, but an unsound popular opinion on a scientific question may bring permanent ruin to a race. It would not have mattered much if the legislature of Indiana had passed the bill fixing a fictitious value of Pi, but it would have made lots of trouble if the engineers and mathematicians of the world had adopted the wrong figure. The fate of the nation depends less on how the people cast their ballots than on how they combine their chromosomes.

THE FOURTH STATE OF MATTER

Now that the kids on roller skates are talking familiarly about vacuum tubes and electron streams, and not merely talking about them but playing with them, it is interesting to turn back the pages of history to the time when these things were new, and nobody in the world perceived their significance but one man and he but dimly.

We do not have to turn back very far, only 45 years, when William Crookes exhibited the vacuum tubes that were afterwards known by his name. He found that when he exhausted the air as completely as possible from a glass tube and then passed an electric current into it by



DR. L. H. BAEKELAND

Elected president of the American Chemical Society. Dr. Baekeland, who is honorary professor of chemical engineering in Columbia University, is known for his discoveries of velox paper and bakelite and for his other important work in industrial chemistry.

platinum poles stuck through the glass that there proceeded from the negative pole or cathode a curious kind of a ray. Where the ray started from the cathode disk it was for a space dark and invisible, further on it became a beam of bluish light and where this struck the opposite side of the tube it made a greenish glowing spot on the glass. That this ray was not ordinary light he proved by holding a magnet up to the tube, for the cathode ray was curved out of its course by the magnetic force and could be turned in any direction, instead of going obstinately straight ahead as a common light ray does in a vacuum.

Such experiments with the "Crookes' tubes" amused the public and amazed the scientists. Everybody admired Crookes' skill as a glass blower and wondered how he got a little windmill inside a sealed tube, even as the King of England wondered how the apple got into the dumpling. But when Crookes claimed that he had in his tubes "a fourth state of matter" and a new kind of radiation and a connecting link between matter and energy his scientific colleagues were skeptical. They felt that he had gone too far, had become a monomaniac on the subject, had, in short, got vacuum on the brain. There were only three states of matter, as everybody knew, solid, liquid and gaseous. To have a fourth state the atom must be split and the very name of "atom" meant something that could not be split. This man Crookes never had a university education anyhow, and he was the son of a tailor, and he said he had seen spirits in the séance room, and altogether it was a bit cheeky of him to bring forward such upsetting ideas on such empty evidence as a vacuum tube.

But Crookes always had the courage of his convictions, and in this case proved himself a true prophet. Two passages quoted from his 1879 addresses in the "Life of Sir William Crookes" by Fournier d'Albe, just published, will show how astonishingly he anticipated the views of the twentieth century:

"The phenomena in those exhausted tubes reveal to physical science a new world—a world where matter exists in a fourth state, where the corpuscular theory of light holds good, and where light does not always move in a straight line; but where we can never enter, and in which we must be content to observe and experiment from the outside.

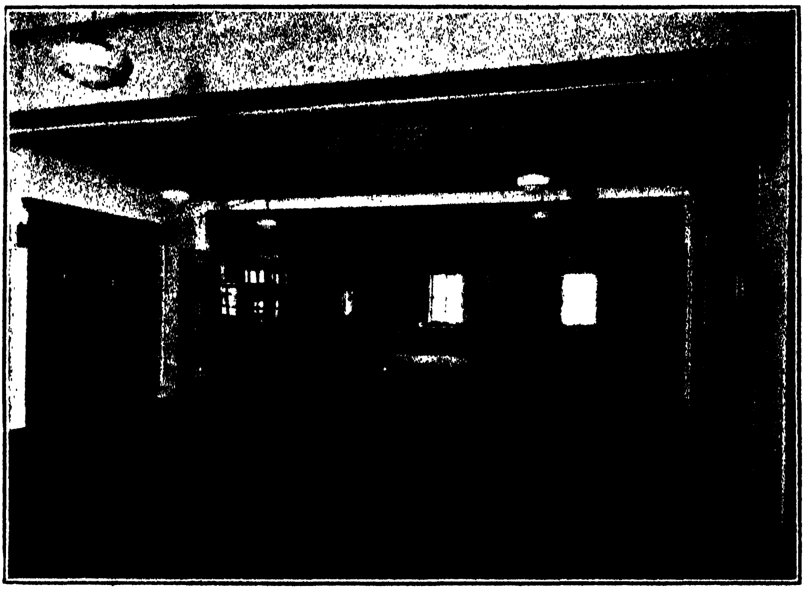
"In studying this fourth state of matter we seem at length to have within our grasp and obedient to our control the little indivisible particles which with good warrant are supposed to constitute the physical basis of the universe. We have seen that in some of its properties radiant matter is as material as this table, whilst in other properties it almost assumes the character of radiant energy. We have actually touched the border land where matter and force seem to merge into one another, the shadowy realm between known and unknown, which for me has always had peculiar temptations. I venture to think that the greatest scientific problems of the future will find their solution in this border land, and even beyond; here, it seems to me, lie ultimate realities, subtle, far-reaching, wonderful."

Yet all these were, when no Man did them know,
Yet have from wisest Ages hidden beene;
And later Times things more unknown shall show.
Why then should witlesse Man so much misweene,
That nothing is, but that which he hath seene.

We now know that the cathode ray of Crookes is, as he said, corpuscular and not vibratory, for it consists of a stream of electrons, which are "the

Baker Laboratory of Chemistry, Cornell University

Erected by the gift of Mr. George F. Baker, at a cost of $1,500,000, and recently dedicated.



ENTRANCE HALL, BAKER LABORATORY OF CHEMISTRY

little indivisible particles" that "constitute the physical basis of the universe," and they do indeed belong to the borderland of matter and energy. They are atoms of electricity and sub-atoms of matter. They change their mass when they change their motion, and where free-flying electrons strike solid matter they start a stream of energy in the form of waves, what we call the "X-rays." If Crookes had only happened to lay a photographic plate holder opposite the green spot where his cathode ray struck the glass, he would have anticipated Roentgen in the discovery of the X-rays by some seventeen years.

But it was glory enough for one man to have revealed the cathode rays inside the sealed tube even though he failed to follow their course outside. Thanks to Sir William Crookes, Londoners can now listen in on Pittsburgh concerts and he foretold the means and method of wireless telegraphy as early as 1892, five years before Marconi sent his first message by radio.

THE FERTILITY VITAMIN

The two chief characteristics of life are growth and reproduction, the magnification and the multiplication of living beings. Essential for both is food. But what kinds of food? This is the question that is being gradually solved by feeding experiments on man and lower animals carried out under chemical control by hundreds of investigators during the last quarter century.

The first thing found out was that there were four main essentials in food: (1) proteins, such as the casein of milk, (2) carbohydrates, such as sugar or starch, (3) fats and (4) certain mineral salts, such as calcium phosphate.

But when these four food factors were prepared chemically pure and mixed together they were found not to form a complete and satisfactory

diet. The animals fed on it failed to grow, or showed certain symptoms of disease. Evidently there was a lack of something or some things. This was a puzzle, for whatever they might be they were too delicate in structure for the chemist to extract, and too minute in amount for him to weigh. They have been named the "vitamins" and distinguished provisionally by the letters of the alphabet. Although nobody has yet seen a vitamin, we know pretty well which foods contain them and what happens if they are wanting. They are defined negatively, as salt was defined by the schoolboy: "Salt is what makes potatoes taste bad when you don't put any on."

If you don't have Vitamin A you are likely to get a certain sort of sore eyes. If you don't have Vitamin B you are likely to get beri-beri. If you don't have Vitamin C you are likely to get scurvy. If you don't have Vitamin D you are likely to get rickets.

With the four main food factors in purified form and the four vitamins pretty well identified, the investigators could now make up an artificial diet on which animals, white rats being usually used, would grow as big as those that were fed on natural food. They were as handsome and happy as any, and lived as long; but they failed to provide for the continuance of the ratty race. Their offspring were few and infrequent, or none and never, which is contrary to the custom in rat families. But the investigators, instead of accusing the rats of race suicide, surmised that this failing might be a deficiency disease, so they set themselves to find the missing vitamin. And they have found it, or at least they have found that there is one. Herbert M. Evans and Katharine Scott Bishop, of the University of California, and Barnett Sure, of the University of Arkansas, have carried on experiments leading to the same conclusion.

It is found, for instance, that on a diet composed of milk casein for protein, cornstarch for carbohydrate, lard for fat, and the proper mineral salts, with the addition of a little butter for Vitamin A, yeast for B, orange juice for C, and cod-liver oil for D, the rats grew normally and thrived, but they failed in fertility. Increasing the amount of the diet or of any of its constituents did not remove the deficiency, but the addition to the dietary of a little lettuce or rice, even the polished kind, enabled the rats to reproduce. Four successive generations have been raised on such a synthetic diet.

It is interesting to recall that rice, which had so marked an effect in these experiments, has a high reputation in the Orient for the promotion of fertility. This significance survives in our marriage customs to-day, and we often see on a depot platform a bridal party showering the young couple with rice in spite of their attempts to evade it. Other foods found to contain this anti-sterility factor are yellow corn, rolled oats, velvet bean-pod meal, dried alfalfa, field pea seedlings, egg yolk and cooked meat. It is missing from milk.

Evans and Bishop have found that the male as well as the female is affected by the lack of this substance, and they have been able to extract it from favorable foods by alcohol and ether. When the extract is added to the "pure food" diet on which the rats were sterile, they gain the power of reproduction. These investigators call the substance, as Roentgen called his rays, "Vitamin X," but Professor Sure proposes to promote it in the alphabet and class it as "Vitamin E."

THE SCIENTIFIC MONTHLY

MAY, 1924

THE DISTRIBUTION OF THE STARS

By Professor HARLOW SHAPLEY

DIRECTOR OF HARVARD COLLEGE OBSERVATORY

The distribution of stars is recognized as fundamental in the study of galactic structure. In particular, the problems that are founded on stellar distribution include the relative frequency of various evolutionary stages of stars, the general space density, the superficial density, and the relation of all these properties to distance from the sun and position in the sky. The discoidal form of our stellar system has long been accepted. The changing ideas concerning the dimensions of the system and the interrelation of its various components have not affected the belief that in the direction of the Milky Way the sidereal organization is much more extended than in directions highly inclined to the galactic plane. The discoidal form complicates the analysis of stellar distribution. Still more complicating is the eccentric position of the sun, and the obviously non-homogeneous character of the neighboring parts of the stellar system.

The point that stands out most clearly, after a considerable investigation of stellar distribution, is the restricted value that must be attached to any analysis that does not recognize the heterogeneity of the neighborhood. Some general studies have recently been made in which galactic latitudes were not differentiated, thus ignoring the discoidal form of the stellar system. Many recent studies have failed to differentiate with respect to galactic longitude, thus largely ignoring the sun's eccentric position and the conspicuous clusters and star clouds, some of which are near at hand. I believe that we are on the edge of the great Cygnus star cloud, and that the preferential drift of rapidly moving stars away from the Cygnus region may be an indication and measure of the velocity of that stellar organization with respect to the galactic system and our local cloud. The studies of stellar distribution should recognize clearly that integrated and undifferentiated results refer to a mixture, in

unknown proportions, of the stars of various streams and semi-independent clusters, chief of which is the local system outlined by the brighter B stars.

Equally important, in the analysis of stellar distribution in this neighborhood, are the large obscuring nebulosities in Taurus, Ophiuchus, Sagittarius and elsewhere, most of which appear to be only a few hundred parsecs distant. The great rift in the Milky Way from Aquila southward through Sagittarius has long been recognized as an obscuring cloud; it is near enough to affect seriously the distribution of stars brighter than the tenth magnitude.

Although the lack of homogeneity in the galactic system will seriously disturb attempts to make close analyses of structure and concentration on the basis of general star counts, nevertheless, a study of the numbers of stars of various spectral types and in different galactic regions leads to deductions of interest in the structural problem. The investigation of the spectra of stars during the last thirty years at Harvard has yielded finally the Henry Draper Catalogue, which contains in nine volumes the positions, magnitudes and spectral classes of a little more than 225,000 stars, classified by Miss Annie J. Cannon. The survey covers the whole sky and extends in places to the tenth magnitude and fainter. Indirectly the catalogue is a source for information concerning stellar distances, and therefore can be used to some extent as shown below for the examination of the distribution of stars in space; but it chiefly serves to indicate the distribution on the surface of the sky.[1] A few of the more general results are described in the present account.

The stars have been grouped into eleven general classes. About 99 per cent. of them fall into the familiar classes B, A, F, G, K, and M, which is a series in the order of decreasing surface brightness and also in the order of progressive change in average color from reddish toward blue. It is of interest that about 20,000 of these stars have spectra so nearly identical with that of the sun that no difference could be seen on the small spectrographic dispersions used for faint objects. The most common classes are A and K, especially in the Milky Way, but it must be remembered that this condition refers to the apparent distribution, since the selection of stars for the catalogue is on the basis of apparent brightness rather than

[1] The Henry Draper Catalogue is contained in volumes 91 to 99, inclusive, of the Harvard Annals. Various discussions of the material have appeared since 1921 in Harvard Circulars 226, 229, 230, 239, 240, 245, 248 and in Harvard Bulletins 787, 792, 796. A detailed summary of the investigation of stellar distribution is published in the Proceedings of the American Academy of Arts and Sciences for 1924.

absolute brightness or distance. If we were dealing with a unit of volume rather than a unit of surface we should find, as is well known, a much different condition; instead of the highly luminous giant stars of Classes A and K predominating, we should find that dwarf stars are extremely more numerous than giants. It is also probable that Divisions K and A are long periods in the evolutionary sequence.

Probably one of the most important results of the discussion of the Henry Draper Catalogue relates to this matter of relative numbers in space. We now know the average real brightness of the stars of several spectral classes and also know that the dispersion about the average is small. For such classes the apparent brightness decreases with the distance from the observer, and is, indeed, a valuable measurement of the distance. We find that the highly luminous Class B stars appear in the Henry Draper Catalogue, with apparent magnitudes brighter than 8.25, when at distances up to 880 parsecs (three thousand light years). But dwarf G stars, such as the sun, must be nearer than 70 parsecs to appear brighter than magnitude 8.25. It happens that the number of B's and dwarf G's on the surface of the sky, in the direction of the Milky Way, are nearly the same, although the volume throughout which the former can be seen is nearly two thousand times as great. We therefore conclude that stars in the phase of development of our sun are actually eighteen hundred times as numerous as the highly massive and luminous B stars, which we believe to be in an earlier stage of evolution. In a similar way we find that the youngest of all luminous stars, the giant M's, now appear but once in space for every 350 solar stars. That there are four or five times as many giant M stars as B stars suggests that few have sufficient mass to attain the highest surface temperatures.

The following tabulation gives the surface and space numbers for those classes where the mean absolute magnitudes can be assumed with some certainty. The second column contains the numbers of stars in a hundred square degrees brighter than visual magnitude 8.25 and therefore within the distance limits computed for the third column. The last column gives the number of stars in a million cubic parsecs. Dwarf stars of Classes K and M are likely to be much more numerous than the dwarf G stars.

Spectral Division	Surface Number	Distance Limit	Space Number
Giant M	17.5	430	22
Giant K	69.0	350	160
B	29.7	880	4.4
A	96.9	340	,250
Dwarf F	18.7	140	'680
Dwarf G	26.0	70	7600

Only the region in low galactic latitudes has been used in the above computation, since in that direction (taking all longitudes together) the change of space density with distance can be ignored in a first approximation. The space explored for the B stars is about 1.5×10^8 cubic parsecs, indicating that the material used is of considerable weight and better represents this part of the galactic system than the similar analyses based on stars within ten parsecs of the sun.

The fact that most of the stars in this part of the galactic system are in the extreme dwarf stage, suggests that the evolution through known spectral types is chiefly a matter of the past; or much more probably it indicates that the changes proceed more slowly throughout the dwarf series than in the early giant stages of low internal density. The relation of speed of development to mass is also involved in the question. Possibly we have only an indication here that large masses are infrequent, and that average and small masses evolve rapidly in early life. But obviously the observed fact is much more certain than any of these suggested interpretations.

Some of the fainter stars in the catalogue are at distances in excess of 3,000 parsecs; such are the stars of Class B fainter than the eleventh visual magnitude and Cepheid variables fainter than the ninth and tenth magnitude. But as a striking illustration of the small portion of the galactic system to which our spectroscopic studies are limited, we may observe that probably more than 95 per cent. of the stars of all classes and magnitudes in the Henry Draper Catalogue are within 1,000 parsecs of the sun. Only about one millionth of the space known to be closely populated with stars is covered at all well by this extensive compilation of spectra.

It appears, however, that the edges of the stellar system are approached in high galactic latitudes for giant stars of all classes. A distinct concentration to the galactic circle is deduced for the B, A, K, and M stars brighter than visual magnitude 8.25 (the limit of completeness of the catalogue). Stars of Classes F and G, however, are very little concentrated, because they are chiefly dwarfs and only those near at hand, in the region of relatively uniform space density, appear in the catalogue.

Figure 1 illustrates the galactic concentration for the different spectral classes. The ordinates for each diagram are the numbers of stars in a region of one hundred square degrees; the abscissas are galactic latitudes. The diagram illustrates not only the concentration but also, when read vertically, they show the relative frequency of the various spectra in different zones.

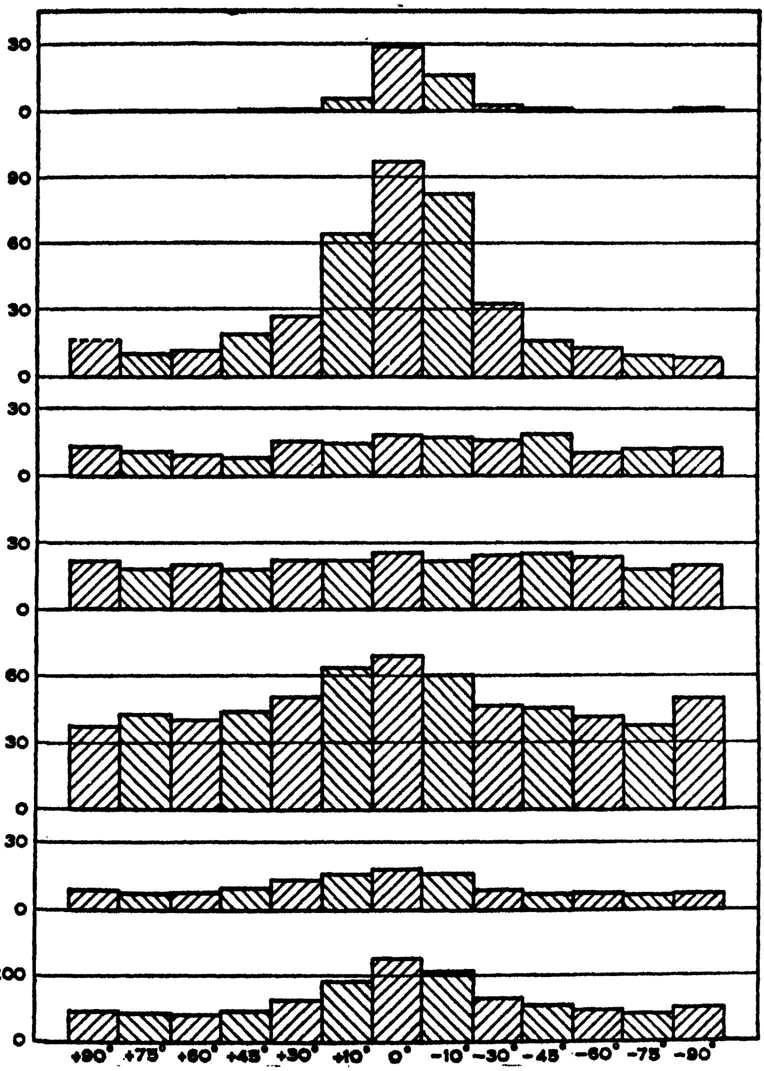


FIG. 1

The most striking feature of Figure 1 is the contrast in galactic concentration between Classes A and F. The former includes subtypes from B8 to A3, and the latter, subtypes from A5 to F2. A closer analysis of the data shows that the rapid change in concentration lies between A0 and A5. This change indicates a very rapid decrease with advancing type in the average absolute brightness of the stars.[3] It suggests that the spectral differences among the early subtypes of Class A may be better regarded as criteria of absolute

[3] Harvard Bulletin 796, 1923.

magnitude than of color and surface temperature. The B stars and early A's are probably concentrated to the galactic plane more than later classes.

In Figure 1 all longitudes were taken together. Figure 2 shows that in different longitudes the A stars brighter than 8.25 differ

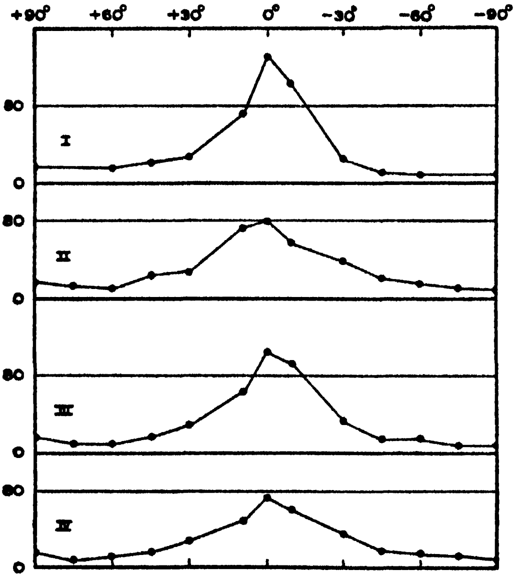


FIG. 2

greatly in galactic concentration. The upper curve shows the concentration in the first quarter of galactic longitude, where the star clouds in Cygnus appear to affect the distribution. The second quarter is affected in low latitudes by the obscuring nebulosities in Taurus and vicinity. The third quarter covers the region of the center of the local system, and the fourth quarter records impressively the influence of the rift in the Milky Way on the distribution of these giant stars of Class A. Since stars brighter than the seventh magnitude also show the rift slightly, we compute that its nearer border may be not more than 200 parsecs distant.

The stars of Class A brighter than magnitude 6.5 are distributed with remarkable uniformity in galactic longitude. The bright B stars, however, show the center of the local system in the constellation Carina. They also indicate clearly that the central plane of the local system is inclined between ten and fifteen degrees to the galactic plane. But the B stars fainter than the eighth magnitude are almost exclusively members of the general galactic system and are highly concentrated to the galactic circle.

When we examine the distribution of the more distant stars, the greater richness of the Sagittarius region is revealed. For instance,

the variable stars of Class M are now recognized as giants at maximum brightness; hence, when the maximum apparent magnitude is faint, they are very remote. They are found to be four times as numerous in the direction of Sagittarius, toward the center of the Galaxy, as in the opposite direction. Similar preference is shown by planetary nebulae, O-type stars, Cepheid variables, the faint B stars and the novae.

The high concentration of faint stars in low galactic latitudes emphasizes the importance of the study of spectra in the Milky Way. Systematic extension of the Henry Draper Catalogue is now being made to fainter stars. But this extension will not attempt to cover the whole sky. Special attention will be given to fields along the Milky Way, particularly those in the northern sky for which the magnitude limit in the catalogue is between eight and nine. In one such field in Aquila Miss Cannon has now recorded 1,567 spectra, of which less than 200 have previously been classified.

CAN THE MASSES RULE THE WORLD?

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No decade in history ever began to witness such momentous changes as those which have occurred since 1914. These changes have been political, economic, cultural and even hygienic, and have been practically world wide. Is there any one dominant trend among all these complex tendencies which have ushered us so suddenly into the new world—for such it is—upon which we look out today? I have long pondered this question, and, as a lifelong student of the deeper currents that control mansoul, have found an answer that seems to me most satisfying, *viz.*, the fundamental impulse that has caused nearly all the troubles of recent years is the growing instinct of revolt against external constraints and control. It is more than kurophobia, or the Freudian resentment against all fatherly authority, and even more than social inhibitions; these are, at most, only its negative manifestations; it is, at root, a new impulse toward spontaneity, self-expression and self-determination, or to live again from within outward. The human spirit is moulting its old carapace, and is beginning to build nobler mansions for itself. Biologically, moulting is a hard process, involving as it does a kind of rebirth, but the new consciousness of freedom it brings is already manifest. Here probably is to be found the best scale by which to measure real progress. Let us, then, specify some salient factors of this impulse of emancipation from outer control.

I

Germany, the most organized country in the world, headed by a monarch more convinced than any in Europe that he was God's vicegerent, feeling its legitimate development impaired from without, sought to break down these barriers by force and extend its sway. In the reaction many crowns fell, the democratic movement became worldwide, and kingcraft in the old hereditary, absolutist sense was found to be either dead or moribund. As I write, twelve countries of Europe, if we include the Sultan, still have royalties at their head. Nearly all of them are intelligent and devoted to making the most and best use of the functions that remain to them; but among them all there is no individual of outstanding ability or power of leadership. In all their political activities they are constrained and directed by ministers far abler than they or by dictators (of whom there are now nine in Europe), who hold all the

power and are above parliaments and independent of constitutions as no king in Europe longer is, and most of whom have none of the prestige of heredity.

There is a pathos about the decadence and passing of the old houses of the Hohenzollerns, Romanoffs and Hapsburgs, and in the present status and prospects of the six to seven hundred personages of royal descent described by F. L. Collins,[1] some of whom are in dire need, and others of whom have subordinate business positions. Moreover, there have long been degenerative processes going on in these families, which are more prone to moral and mental defect than the better families over whom they have reigned.[2] In fact, there are many other conditions in the lives of monarchs that are essentially anti-eugenic, and, although the farewell which even romance, tradition and fashion give them will be a sad one, not only the *Zeitgeist*, but the great Bio-Logos, or spirit of life, has decreed the extinction that the regal function is now undergoing.

We are told that dictatorships mark an ebb in the high tide of democracy. There could be no greater mistake. These dictatorships are simply the crude weapon that the masses, whether civil or military, have seized to batter down opposition to their progress. If popular support should fail, any dictator would lose power in a day. True, in the past dictators have usurped the temporary power delegated to them, have established themselves by force, and have become tyrants. But this is now increasingly difficult, for public opinion and sentiment are more and more dominant throughout the world, and even armies are more and more subject to it. Professional soldiery, always the strong arm of tyrants, has declined, and armies are composed of a citizenry only temporarily under arms for a specific purpose and for a limited time, and hence are more under the control of home opinion and sentiment.

In modern times parliaments, congresses and legislative assemblies of various names, composed of representative delegates elected by the people, have taken the place of and greatly reduced autocratic power, and as a result we have in all progressive lands a vast and growing body of legislation, wise and otherwise, enforced or unenforced, and sometimes covertly or openly defied. This was a great step in the progress of democracy. These bodies have often acquired great power and autonomy, sometimes rivaling and seeking to dominate the executive branch of government, and occasionally defying, or even electing or deposing, its members. But the power of such bodies is limited by the minorities within them, by frequent elec-

[1] "This King Business," 1923, p. 220.

[2] F. A. Woods, "Mental and Moral Heredity in Royalty," New York, 1906, p. 212.

tions, the ever-present regard for coming elections, and also, especially in this country, by powerful lobbies imposing petitions, and by the initiative, referendum and recall, till the old independence and autonomy of members is gone and they are practically reduced to the condition of mere delegates dominated by other forces than their own insight and conviction. They are instructed and restricted, too, by platforms, and bound by party fealty and the dread of defeat and consequent loss of the vast power of patronage, which has nearly quadrupled here within the decade. Here, too, particularly, the old trust in the wisdom of those we send to congress has given place to distrust, and much of the business of the country is anxious and unsettled when congress is in session, while all are confused by the hundreds of new bills introduced every year in not only the national but state legislatures—a single member of the former often introducing scores of new measures and pressing for their consideration.

Distrust of all authority is inherent in all democracies. They rarely recognize real leadership, and have, as Faguet showed, always tended towards the cult of mediocrity, the best man and measures being often rejected for those that are second or third best; while the boss, whom they trust and exalt to power, is one whom they deem represents their own mental and moral level, vaunts himself as the servant of their will, and whom they regard as the protagonist of their own emancipation from all outer constraint.

Thus all political power is to-day, at least, within reach of all. The masses can exercise it themselves, or can delegate it, or any part of it, to whom they choose for a time. And they realize that they can at any time resume and exercise it all by direct or by indirect action. The only form of tyranny in this field that is still possible for them is that of majorities. Not only are all positions open to all, but the vote of the poorest, most ignorant and vicious citizen has the same weight as that of the wisest, best and wealthiest. This ideal of government of, for and by the people is as stupendous and revolutionary as it is novel in the long history of mankind. Indeed, nations and races have been accustomed for so many millennia to being governed by others that they have not yet realized what political freedom means, or their new responsibilities under it, or the dangers it involves; and, least of all, how fundamentally successful self-government of the state rests upon the power and habit of self-control and self-regimentation of individual citizens.

Never were all these considerations more pressingly opportune when we realize that within the decade Germany, most of the Austrian countries and Balkan states and China have become republics;

that the overseas possessions of the British Empire have assumed greater independence—Ireland has become free, and India is fuller than ever of the seething spirit of revolt—and that the king of this great nation, on which the sun never sets, has just had to give his government into the hands of a labor cabinet; while the kings of Italy, Spain, and even the Sultan, have been eclipsed and robbed of all real power by dictators, and that the next decade or two will probably show the world whether or not democracy can be made safe and salutary for the world.

II

The church has lost its old authoritativeness. Two thousand years of the influence of the Prince of Peace did not prevent avowedly Christian nations from flying at each other's throats in a war in which Protestants fought Protestants and Catholics fought Catholics, each side praying to a common God to aid them in slaughtering the other. Only those who can sense the deep and strong psychic currents and their trends in the soul of man can begin to realize how disastrous to ecclesiastical and credal loyalty within Christendom, and how fatal to whatever respect and influence it had upon unbelievers or those of other creeds and races all this has been. The damage to faith thus wrought is only thinly camouflaged by the excellent ameliorative services done by representatives of Christian organizations in the armies.

Again, fundamentalists and anti-evolutionists have not only alienated the intelligentsia from the church, but brought upon it new reproach, if not contempt. The preposterous discussions and schisms about the paternity of a personage born obscurely two millennia ago, the tactless heresy charges and trials, the idiotic interpretations to the effect that the end of the world is at hand, and that Jesus is about to come and sweep to destruction all but the few elect, as the vociferous yellow religionists proclaim—all this suggests not so much ignorant pilotage of the grand old ship of salvation, but the work of scuttlers of it working from within. No higher criticism or aggressive heresy ever began to discredit belief in piety as organized and administered by the church. Despite all the cleverly arranged figures intimating gains, the best of all statistics of the vitality of a religion is actual attendance upon public worship, especially in the Protestant lands, and these show, as we should expect, a very marked relative falling off; while secular activities—the newspapers, movies, games and, in summer, above all, auto trips are fast absorbing the time once given to the church on Sundays. Moreover, reliable results of various investigations also show that with every year of secondary and higher education, the proportion of the rising generation who believe even in the more

fundamental doctrines of a personal God, a future life, miracles, and the inerrant validity of inspired Scripture, diminishes. The time has passed when intelligent and thoughtful men and women will submit their belief or non-belief about the basal problems of life and the conclusions of science to an ecclesiastical visé.

The best thing about this rising tide of dissent is that it is reverent toward true piety, and insists upon religion, rejecting only dogma, the efficacy of rites, the assumption of infallibility and finality, and the monopolization of the way of salvation, which constitute the essence of ecclesiasticism. But, you say, the shamans and whirling dervishes of revivalism still succeed with their incantations:

> At the last convention of the International Bible Students' Association at Los Angeles, 30,000 were led by a spell-binding judge to resolve unanimously that "goats" and enemies of the church within it "have with selfish design invaded the schools, colleges, seminaries and universities, with their God-destroying doctrines of higher criticism and evolution," and so forth; that "blaspheming his name" by "a Satan-directed League of Nations" wrought a long list of evils; that "the end of the world has come," and that they should withdraw from the denominational churches as representing Babylon, and so forth.

Doesn't this show an ebb in the tide which runs so strongly away from the church? I answer no, any more than dictatorships in Europe are anti-democratic! The whirlwind exhorter eclipses the pastor for a time, as the dictator does the King. He flouts old formalities, and he wins approval from his hearers because they want a rebirth of a deeper piety, a more direct and unproscribed access to the All-Father, and sympathize with his criticisms of the church, for it is just these "slams" that "get" his hearers. He carries them away with him for a time, but as they are not led into any promised land they soon settle back to their former listlessness because they are not really fed, and only the instinct of revolt is strengthened and remains. Indeed, so far has religious freedom progressed in any intelligent land that almost any one, save only clergymen, can hold and express religious opinions, even the most radical, without prejudice to his economic, social or political standing. All tolerate because all doubt.

III

Gone, too, or fast going, is the old authority of the home. The flapper feels that her mother and all her ideas are antiquated, and she is inaugurating a new type of emancipated young womanhood. We must believe, too, that on the whole her revolt is beneficent. The boy, almost in his infancy, Freudians tell us, or at least long before he knows it, begins to hate and even to feel jealousy toward

his father. Especially do the children of foreign families which land upon our shores—all the more if they speak another language—soon learn to become ashamed of their parents and their ways. The school eclipses the influence of the home, and, as it becomes more and more paternal, of the parents. The homes of the poor, especially in the cities, are less and less attractive to the young. In modern society parents have less and less to do with their children, and thus both discipline and respect have declined.

IV

The "youth movement" is now almost worldwide. When the nations were enlisting men for the great war, and also to hearten those conscripted, they were told that it was a war to end war, to make the world safe for democracy, to usher in a better era. Not only have these promises not been realized, but youth everywhere came home from the war disenchanted. They had learned that, in Sherman's phrase, war was "hell," and their slogan was "never again!" But, worst of all, they found themselves in a world of hunger, poverty, burdened with war debts and their own entire lives in the future dismalized. No wonder, then, that they distrusted the older generation, which they felt was responsible for it. Most of these movements tend back to nature, or at least to a simpler and hardier life. There is little unanimity, but an intense and seething idealism. Some of the traits where the young now go far beyond their elders are an open new diplomacy, internationalism, the reform of the educational system, more democracy, work combined with study and mutual help. Youth is striving toward—to use the slogan and titles of their many little journals that have sprung up everywhere—a new religion, new light, new man, a new age, a new state, new economic relations and peace. In Australia they demand the abolition of armies, navies, forts, submarines and so forth. In the Latin-American countries their efforts are directed toward political and to the most radical educational reform—in France to a new university and a new type of lycée, and so on, in ways we have no time to specify here. The movement is more fully developed in Germany, where most of these movements, of which there are many with diverse ends, hark back to the period before the war of 1870 to that of Goethe, and even to the primitive Germania of Tacitus, although there are counter trends toward Catholicism and even Prussianism. It is least developed in this country, where even in the forty odd student forums it is somewhat exotic, because student life here is so absorbed in extra-curricular activities. In all countries older people look upon it very differently. A few almost apotheosize and others anathematize it. There is one thing, however, in which almost everywhere there is unanimity, and

that is that there must be no more great wars, and it is just at this point where a strike of youth against militarism could have deadly effectiveness. All these forms of protest are expressions of the new spirit of emancipation from authority that is sweeping over the world, and this means a more radical democracy. Everything looks, therefore, to a resumption of authority by the people.

If this is fated, we have to ask what is to become of civilization. If Plato was right in regarding the Demos as a beast, or, if the Le Bon school of thought is right that it means "mobocracy" or "moronarchy," if the war tests that show the average psychological age of our army as thirteen years are correct, do we not have cause for despair? Must we not expect a general *débâcle* of culture? This is the question of questions that confronts us to-day. It seems to many like a relapse from the control of reason to that of instinct, and it is here that pessimism has its stronghold, and some even urge that the democratic ideal is the one great and vital illusion of the modern world.

We believe this is all wrong, and that the people can be trusted. Let us take the broadest possible view, and then I think we shall find hope at the bottom of the Pandora box.

(A) Language, with its wonderful intricacies, its copious vocabularies, its complex but always logical structure, is not a creation of individuals but of the masses of mankind. It was built up slowly from the contributions of innumerable individuals. The same is true of the vast structure of myth and folklore found everywhere. The Zulus had unwritten *mores* which the English in South Africa found so excellent that they substituted them for common law in dealing with crimes against both property and person. The great traditions of races, sometimes dignified by the name of Bibles, were the slow evolutions of races—"Out of the heart of nature rolled the burden of the Bibles old." Durkheim and Levy-Brühl think that groups of primitive men working together bring a kind of afflatus, so that great forward steps are chiefly taken in corrobories, and the apostles of "Proletkult," who would sweep away most of the existing literature and create a new one, think this must be done by joint efforts of mind stimulating mind. The mythopeic faculties have created in their crude forms the very basis out of which all literatures and philosophies sprang, and we are constantly finding new meanings here.

(B) One of the chief reasons why we distrust and underestimate the folksoul is that we do not realize, and indeed have been taught to disbelieve, that it created religions, including all gods and supernal beings of every kind, all heavens and hells and everything else that we falsely call supernatural. There is a sense in which it is true that gods made men, but a larger and older truth is that men

have made their gods in their own images and projected them into the sky. They have had great leaders and religious geniuses who have led them and who have suggested beliefs in all that is transcendent, but the main fact is that it is the acceptance of these suggestions by the masses that gave them all their significance. Thus, when we think we are worshipping God, we are really worshipping the sublimized creation of the soul of mankind which, in this image, has embodied all the best that it has ever been able to conceive. The world needs this insight now as never before, because nothing gives man such confidence in his own intrinsic nature. The common belief that divine beings and events came first is really treason to human nature and fatal to saving faith in it.

(C) All the civilizations of the world, its cultures, its governments, institutions, literatures, science, states, churches and all kinds of organization—these, too, were made by great numbers of men acting together, often for a long period of time and over a wide extent of space. These have decayed or been destroyed over and over, and men have passed through trying periods of *débâcle* and relapse toward barbarism. But mansoul is unconquerable and irrepressible, and it has always sooner or later evolved other forms in all these domains, and best of all there has been general progress. There is often a tendency to ascribe developments that have required centuries of cooperation, conscious and unconscious, to a single man—Homer, Moses, Hamurabi. Sometimes these personages have been purely mythical, and sometimes historic, like Confucius, Buddha, Jesus, Mahomet; but in all these cases the scene was set, the play staged and the leader came, or was fancied to come, embodying the *Zeitgeist* which always produces the right man when needed, just as the chief actors and the play itself in the Attic theater evolved from the chorus. Men do not realize that the power to appreciate a great or good thing and the will to accept it are made warp and woof exactly of the same psychic stuff as is the power to create them, and differs from originality only in degree. We pass to more specific bases of confidence in the masses now so rapidly everywhere coming into power.

(D) Take the Carnegie Hero Fund, which has already given some 1,200 awards, with some 5,000 on their waiting list, to those who have saved the lives of others at the imminent peril of their own. Nearly all these heroes, the majority of whom are young, are from the middle and lower classes, and their acts were unpremeditated, spontaneous and instinctive, showing how altruistic and self-sacrificing gregarious man is at bottom.

(E) Who has not been struck, too, with the fact that on the stage the gallery gods, and in the movies the more popular audiences, always approve every act and sentiment that is noble, and

mete out their disapproval at all character and conduct that is mean and ignoble; and what novelist would dare to violate the imperative demands of his readers that the favorite character should always win the girl, money, fame and every kind of conflict, although the odds sometimes seem to be incredibly against him, while the villain also must get his "comeupance." This shows that human nature is sound to the core when it comes to making fundamental judgments which are always moral.

(F) Woman, too, has very lately everywhere come to the fore, intellectually, socially, in politics and even in business. Her very nature is more altruistic than man's. To borrow the phraseology of the latest and best exponent of her "cause," Madame Lombrosa, she is by nature alterocentric, while man is egocentric. Her interest and her life are in and for others. This is now one of the chief safeguards of the world against the overwhelming self-seeking that marks our era.

(G) Youth, too, which in its generous trends is so akin to the best that is in femininity, is the predominant characteristic of our country, which is young compared with others, not merely in years but in spirit. America is less controlled by its traditions which are few and brief, and has far more regard for the future than is found in any other land. We are generous, and our charities, especially of late, have been unprecedented, because our sympathies have transcended political limits and have become cosmic in their extent.

Finally, if we have a national trait at all comparable with the German *Gemüt* and the French *esprit*, it is common sense, which might almost be called our muse. It may be limited in its scope, but it is the very culmination of sanity. It is the power to judge great things and persons by common every-day standards, to find the key to what is remote in time, space or even race, in what is right about us every day. This, perhaps more than anything else, is the leaven that makes out of all the races and nationalities that have composed our population the true Americanism so often demanded and so often misunderstood.

V

Besides all this, there are certain safeguards which democracy must more and more recognize and make effective. The first of these is eugenics, which is often called the religion of the future. We must give more regard than hitherto to health of body and mind, and to the laws of human stirpiculture. Civilizations of the past have declined because the psychological and physiological laws of breeding were disregarded, and the human stock decayed. Again, education must at every point supplement heredity. From a practical standpoint it is idle to quarrel as to which of these two is the most important; both are essential in democracy. McDougall, who

sees salvation only in eugenics, and H. G. Wells, who insists we must decuple our expenses and equipment for education in order to salvage the race, are partisans. Both these causes must work together in span to make sure of the future, for the breakdown of either means decay.

Finally, I would add that both culminate in the sublimation of love. How far this is achieved or failed of is just now being revealed as the chief factor in human destiny. I believe that the voice of the people is the only authentic voice of the only God there is in the world of men—hence that democracy is the only true theocracy; that men, individually and collectively, were meant to be a law to, and to rule, themselves, rather than to be governed from without; that human nature with all its faults is preponderantly good, and can safely be trusted, because most of its faults and defects are due to repressions by outer authorities which cause arrested development. To-day mankind is reaching its majority, declaring its independence and faring forth on a new Grail quest for real freedom. Instinct and the unconscious are older, better organized, quicker acting and saner than reason or consciousness, somewhat as the lowly life portrayed in "Main Street" and "David Harum" is more truly representative, more interesting and essentially truer to life than are stories of courts and upper-tendom. Indeed, there seems to be a deep impulse beneath and dominating civilization to submit occasionally all its *thun und haben* to the assay of the average man and his saving oracle of common sense. In fact, in a democratic age this is the only tribunal of last resort.

Thus, I have no grave fears of anarchy, bolshevism, scepticism or even of atheism, *Proletkult*, red propaganda, the new woman or the youth movement all of which are so often "viewed with alarm." All these phenomena mean emancipation from old repressions, and a larger liberty. Hegel was right. The best of all measures of human progress is growth and the consciousness of freedom, and this is just as true whether the method of advance be by evolution or by revolution.

On the other hand, we must not forget that democracy in the present meaning of that term is a very new thing in the world. It has, in fact, only just begun, and has a far longer and harder road yet to travel than it has had so far. Hence, its chief assets today are not in its achievements but in its ideals. Most of its beckonings are mirages that never can become real. What is its ultimate goal? I answer that it is a country, state and world in which each individual does what he can do best and is rewarded according to his service. Each will be not only tested from childhood on, but assigned his grade, and be assured the place that allows the freest

scope for doing the best that is in him. We do not begin to realize the difference between individuals outwardly nearly alike.

Some are born to be hewers of wood and drawers of water, and are fortunate if they can be made self-supporting; practical slavery under one name or another must always be their lot. Every civilization has always had and will forever have its drudge class, and no advance in machinery will ever relieve them of their fate, but can only mitigate it. But even they must never be exploited, but enjoy the full reward of all they do, and, above all, should have at every stage of life the door of opportunity kept wide open. Every kind of ability must be dedicated betimes and recognized. So different in gifts are men that if there were to be a Hebraic Jubilee every fifty years, each half century would develop perhaps almost as great inequalities as before. Such a divvy would also give each but a very small portion of what he wants, so that there is always a vast, unsettling and dangerous surplus of unfulfilled wishes. The peril of democracy is that it has aroused so large a body of hopes that are utterly unrealizable. Hence, abhorrent as it is, we must prepare the way for a gospel of renunciation. Most people, at the present time, demand too much of this life, especially now that the belief in another is fading. Ranks and classes are inherent in human nature. Perhaps Goddard's dream will come true, and each must accept the rating that consigns him his true and just place in the hierarchy of the world's work.

Before that comes, however, we must work out the tremendous problems of capital and labor, of the tyranny of majorities, the monopolization of public utilities, and the dethronement of special privileges, especially those that come by inheritance.

The one outstanding trait of the "youth movement," now almost world-wide, is the unification of young intellectuals with labor. This in a generation will make the latter articulate and powerful as never before. Men had to be inspired by extravagant expectations to launch out on the uncharted sea of democracy. Like all dreams, this will have to be reinterpreted, and what they mean found underneath what they say—and these two are very different. But because the human spirit has faced and solved so many other problems, just as difficult if not more so compared with the resources at its command, we believe it will muddle through those that now confront it. We believe this because, and only because, we believe that human nature, however crude, is on the whole still sound at the core. If not, we are lost, and the last great hope of the world will prove its direst delusion.

RECENT DEVELOPMENTS IN PREHISTORY

By Professor GEORGE GRANT MacCURDY

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ONE of the most important developments in the field of Prehistory is the general recognition of the existence in the Upper Tertiary of a human precursor capable of utilizing and chipping flints; this recognition confirms the views held and expressed by the present writer since 1905. Although sufficient evidence on which to reach a positive decision existed at that time, it has taken the discoveries by Reid Moir in East Anglia during the past fifteen years to produce the cumulative effect necessary to convince the more hardy doubters.

Piltdown: Recent investigations and discoveries bearing on human and proto-human skeletal remains are in keeping with the above cited views of the writer concerning the existence of a flint-chipping Pliocene precursor. New light on the man of Piltdown has been furnished by the discovery of additional skeletal material some two miles distant from the original site. It includes a small portion of the occipital, a portion of the right half of the frontal with a part of the orbital margin, and the first (or second) lower left molar. These pieces are in the same chemical condition as the human bones from Piltdown and belong to the same type, even to the relatively great thickness of the cranial wall. In fact, the fragment of the frontal and the tooth might have belonged to the skull and lower jaw from Piltdown, although there is a very slight difference in tooth wear. But the occipital fragment must belong to another cranium, for the same part of the occipital is present in the Piltdown cranium. One can say that these last-found fragments represent at least one additional individual.

If the Piltdown cranium and lower jaw belong to one individual, and if the tooth and cranial fragments from the new site all belong to a second individual, the evidence afforded by the new discovery, although based on small fragments, would confirm, in so far as it goes, Smith Woodward's original conclusion that the Piltdown cranium and lower jaw belong together. It is scarcely within the range of probability that twice in succession an association of fossil human and chimpanzee bones should come to light and that in each case the association should consist of identical parts, namely, the cranium of man and the lower jaw (or rather a tooth from the same) of chimpanzee, unless perchance the new lower left molar belongs to the lower jaw of Piltdown; if this be true, it would

materially strengthen the view that the Piltdown cranium and lower jaw do not belong together. The cranium is everywhere thick and heavy for its size; the same is true of the additional occipital fragment. The lower jaw is of a wholly different type—graceful, shapely, relatively light in comparison with its size.

A radiographic study of the teeth of Piltdown, Heidelberg, Krapina, Ehringsdorf and modern man as compared with the teeth of the higher apes, supports the view that the teeth of the Piltdown lower jaw are human and not ape-like. In man, both fossil and living, and in Piltdown, the pulp cavities are relatively much larger than in the higher apes. The crown height of the Piltdown teeth is comparable with that of fossil man and considerably greater than that of the chimpanzee. Thus, the Piltdown dentition is to be classed in this respect with that of *Homo heidelbergensis, H. neandertalensis,* and even with that of recent man, all of which are hypsodont, rather than with the low-crowned or chamaedont dentition of the chimpanzee. It is possible that the Piltdown jaw represents an older type of man than do the two Piltdown crania.

The latest reconstruction of the Piltdown skull by Elliot Smith and John Hunter has brought to light additional primitive cranial characters that are in keeping with evidence furnished by the discovery of the second individual and with the assumption that cranium and lower jaw belong together. They find that the occiput is much shorter than was originally supposed to be the case. This brings the cranium more in keeping with the lower jaw in so far as type is concerned and gives a cranial capacity not exceeding 1,260 cubic centimeters.

All the new evidence seems to point in one direction, the one which would lead to a correlation of cranium with lower jaw. The cranium is human but belongs to a primitive type hitherto unknown, wholly different from the Neandertal type and even the Heidelberg type. The lower jaw is ape-like but not necessarily that of an ape; although more primitive than the cranium, the association of the two, if not based on positive data, is at least not an anatomic impossibility. There is also ground for referring the jaw to an earlier and more primitive type than the crania.

It was the author's good fortune to examine the original Piltdown specimens in 1922. In the exhibition room of the South Kensington Museum, Smith Woodward had placed on view a cast of the lower jaw (right half) fitted to the left half of the lower jaw of a chimpanzee. The author noted that the outer line of symphysial contact was longer on the Piltdown half than on the chimpanzee half, although the two rami were approximately identical in size. This means that the post-symphysial platform is even more

pronounced in the Piltdown lower jaw than in the chimpanzee. In order to surmount such an anatomical obstacle, one must invoke a wider range of individual variation within the genus *Homo* (*Eoanthropus* included) than has hitherto been considered ample.

One can not accept the association of cranium and lower jaw and still remain skeptical regarding the association of the canine tooth with the lower jaw. The second discovery did not include a canine tooth. The Piltdown canine was found later, but at a spot near where the lower jaw had been found. It is more ape-like than the molars and is the only canine thus far discovered. Its right to a place in the dentition of the man of Piltdown comes partly through the exaggerated chimpanzee slope in the symphysial region of the lower jaw and partly through default of other claimants. This right would most certainly be questioned should another less ape-like canine be found at Piltdown.

Pithecanthropus erectus: Further researches into the nature of the remains of *Pithecanthropus erectus* found by Dubois at Trinil, Java, tend to confirm the view that a human precursor capable of utilizing and chipping flints might well have existed as long ago as the Upper Tertiary. Although the *Pithecanthropus* remains were for a time inaccessible to anthropologists, Dubois has continued his studies, especially of the endocranial surface of the skull cap. He finds it to be perfectly preserved; the region of the Broca convolution, the seat of articulate speech, is quite different from that in any known ape's brain. The making of an endocranial cast has enabled Dubois to revise his estimate of the cranial capacity which he now places at 985 cubic centimeters (instead of 850 cc), a figure slightly larger than the minimum (960 cc) among the Veddahs and much larger than the cranial capacity of the adult male gorilla (550 cc). *Pithecanthropus erectus* is, therefore, much nearer to *Homo* than was at first supposed. Both Hrdlička and McGregor, who were so fortunate as to see the originals last summer, would place *Pithecanthropus* much nearer to man than to any known ape. The fragment of a lower jaw with the first (or second) premolar and the socket for the tooth immediately in front was found in the same horizon as *Pithecanthropus*, but at a distance of some 40 kilometers (25 miles) southeast of the Trinil site; judging from its appearance, this fragment might well have belonged to another individual of the same genus.

Ehringsdorf: To the adult human lower jaw found in travertine interglacial deposits at Ehringsdorf near Weimar in 1914 there has been added the fragmentary skeleton of a child ten years old, including the lower jaw. The latter has points in common with the lower jaw of the adult, such as absence of chin and a sort

of post-symphysial platform. The ascending ramus which is present in this child resembles the Piltdown lower jaw more closely than it does that of Mauer. The Ehringsdorf human skeletal remains were found associated with flint artifacts and a warm fauna; they are older than the remains of Neandertal man associated with a cold fauna.

La Quina: Dr. Henry Martin's discovery of the cranium of a Mousterian, or Neandertal, child about eight years old in the rock shelter of La Quina (Charente) has added appreciably to our knowledge of Neandertal racial characters. The cranium is nearly complete and shows very clearly the rudiments of all the special characters that appear in the adult; dolichocephaly, low forehead with frontal protuberances, prominent brow ridges which span without a break the space above the root of the nose, diminutive mastoid processes, and big round orbits. Happily, the framework of the nose is complete, showing that the Neandertal nose was not so flat as some had been led to believe. This cranium of a child differs enormously from the cranium of an eight-year-old *Homo sapiens* and indicates that Neandertal cranial morphology is very old as well as specific in character.

Solutré: The type station of the Solutrean Epoch also contains an Aurignacian horizon; in this horizon, at the classic station of Crot-du-Charnier, a discovery of capital importance was made in 1923 by Drs. Mayet, Arcelin and Depéret, who uncovered three Aurignacian burials *in situ* beneath the horse magma. The bodies had been left in extended position with the head in each case to the west. Near the first burial, that of a young adult female, there were found the fragmentary skeletons of two very young children. Burial Number 2 was that of an adult male, as was likewise that of Number 3. The three formed a linear series running east and west; in each case two stones had been placed at the head (one on either side).

A detailed study of the three adult skeletons is being made by Dr. Lucien Mayet, of the University of Lyons. The two males were tall—1.83 and 1.75 meters (6 feet and 5 feet 10.5 inches), respectively; their skulls have a cephalic index almost too large to bring them within the dolichocephalic class. They are said to be more like the man of Cro-Magnon than that of Combe-Capelle. The stature of the female is estimated at 1.55 meters (5 feet 1 inch). Some of the sepultures found in the Crot-du-Charnier at an earlier date were no doubt of Aurignacian age as had been stated by Obermaier.

Cultural Evolution

Switzerland: There have also been important developments in the field of cultural evolution. A recent discovery proves that inter-

glacial man was able to support himself at great elevations in the Swiss Alps. Emil Bächler has discovered a cavern at a height of 2,445 meters (7,946 feet), near the top of Drachenberg, southerly from Ragatz. This cavern, very appropriately named *Drachenloch,* is in the heart of the Alpine field of glaciation; it contains not only human cultural remains but also fossil animal remains. The nature of these is such as to preclude the possibility of their being post-glacial; they must therefore be referred to the last interglacial (Riss-Würm) epoch. The abundance of cave bear remains (averaging more than 95 per cent. of all the fossil animal remains) in Drachenloch is an interesting phenomenon and no doubt due to the fact that the interglacial hunter brought his favorite game animals there as booty. The bones are never in anatomic relation; they are not water worn, hence could not have been washed in, and the deposits are not due to water action.

The Cult of the Cave Bear must have held sway at Drachenloch. Bächler found altars on which skulls and long bones of the cave bear were placed in orderly fashion; the skulls were oriented so as to face the cavern entrance (also exit since it is a blind cavern). This proves that something akin to the religious instinct was already developed long before the cave-art period and the appearance of the early Cro-Magnons in western Europe; it even antedates the Neandertal race associated with a cold fauna.

The Drachenloch hunter improvised a bone tool consisting of a cave-bear fibula for skinning and preparing the hides of the cave bear. The bone was broken obliquely near the center and the broken surface was polished for and by use; the proximal epiphysis was employed as the handle. Bächler found 31 specimens arranged on a flat stone so as to bring the handle always at the same end of the pile; some of these specimens had clearly seen service as indicated by the wearing down of the broken end. Distal ends of the fibula were also found, but none of them showed marks of use; the distal epiphysis obviously did not fit the hand so well as the proximal. Bone splinters and canines of the bear, split longitudinally, were utilized as pointed implements.

The innominate bone of the cave bear was made to serve a variety of uses through the removal of the distal ends of the iliac, pubic and ischiac portions; the margins often bear marks of use. Such tools admit of service in a number of ways: as a skin scraper, or as a vessel for holding water, blood or oil (lamp). Specimens of this sort occur by the hundreds at Drachenloch, as many as 25 or 30 having been found in a single heap.

Siberia: New light has been shed on the character and geographic distribution of Upper Paleolithic culture by Gero von

Merhart's discoveries in the loess of the Yenisei valley, Siberia. The sites explored by von Merhart are in the vicinity of and to the south of Krasnoyarsk. They, as well as the previously known station of Afontova, belong to the Upper Paleolithic (probably Magdalenian) with a Siberian facies.[1] Similar finds have been reported from Wercholensk Mountain near Irkutsk by B. E. Petri, and from China by Father Teilhard de Chardin.

France: One of the most active of the cave explorers in France is Dr. R. de Saint-Périer. For the past dozen years he has explored a group of caves (grotte des Harpons, grotte des Boeufs, grotte des Rideaux) at Lespugue between Saint-Gaudens and Saint-Martory (Haute-Garonne). All three of these caves have yielded portable examples of Paleolithic art as well as artifacts: engravings of the horse on bone, harpoons of reindeer horn, a stone lamp, etc., from the grotte des Harpons; bone javelin points, bone needles, baton, engravings on bone, and a fish (probably flounder) in bone with the contours cut away, from the grotte des Boeufs; bone javelin points, flint implements, and an ivory statuette of a human female (Venus) from the grotte des Rideaux. This last is of special importance because practically complete, of fine workmanship, and of a type especially favored by Aurignacian artists. Statuettes and relief figures of the same general type had been found previously at Brassempouy (Landes), Laussel (Dordogne), the Mentone caves, and Willendorf (Lower Austria); while in 1922, Dr. Otto Schmidtgen found the lower half of two female statuettes of this type in the loess within the city limits of Mainz on the Rhine.

The ivory statuette from Lespugue surpasses in length any other one of the group, although by no means as large as the reliefs from Laussel. It has the characters common to all—undifferentiated features, large pendant breasts and mountain of Venus, enormous hips, large thighs, slender arms, and legs diminishing from the knee down—but resembles the Venus of Willendorf more closely than any other. Unfortunately, the pick of the workman injured the statuette in the region of the breasts; the restoration serves to emphasize the close resemblance to the Willendorf specimen. The pose is exactly the same even to the resting of the lower arms on the breasts and the outlines tapering from the hips in both directions. They are as much alike as a tall slender figure can be like a short stocky figure of the same general type. The artists who made them were both masters of the same canons and traditions. The striking similarity of these two figures throws a flood of new light on the homogeneity of Aurignacian culture over a wide geographic area. If specimens of this kind can still be found in the caves of the Dor-

[1] *Amer. Anthropol.*, N. S., XXV, 1–55, 1923.

dogne and Garonne valleys, the caves of Grimaldi, and in loess of the Danube and Rhine valleys, the probabilities are that they once existed at all the principal Aurignacian settlements in central and western Europe.

During the summer of 1923 the region between Saint-Gaudens and Saint-Martory was made to yield more of its cave-art secrets. A prediction made by the present writer in 1913 after Count Begouen's discovery of bisons modeled in clay at Tuc d'Audoubert (Ariège), that such figures were common to many Paleolithic caverns but had been destroyed, was literally verified last summer by Norbert Casteret's discovery of many animal figures modeled in clay in the cavern of Montespan (Haute-Garonne). Chief among these is a large headless bear, 1.10 meters (43.3 in.) long; the presence of a bear's skull between the forepaws of the model leads Casterest to conclude that the latter might have been provided with a real bear's head. The body is covered with dart thrusts. Around the bear were some twenty smaller clay models in relief rendered unrecognizable by the action of dripping water; the three best preserved are horses with ample paunches and abundant mane and beard. Elsewhere there were three large feline figures (1.50–1.60 meters) leaning against the wall and much damaged; the breast of one is marked by numerous javelin thrusts. A horse's head in clay about the size of a man's hand was discovered in the same gallery. On a bank of clay Casteret found half of a woman's body modeled in clay, also several clay balls.

That the artist purposely mutilated some of the models by means of numerous dart stabs is a performance full of magic significance. It seems that the Montespan clay models were never so perfectly formed as were the bisons from Tuc d'Audoubert; the latter were chosen apparently to live for breeding purposes, while those from Montespan were marked for death at the hands of the hunter. No text could be more eloquent of the true meaning of cave art than these mute but by no means inglorious witnesses from Tuc and Montespan, testifying to the caveman's need for clothing and sustenance, and to the magic means invoked in his behalf.

In addition to the clay models, Casteret found at Montespan mural engravings of the bison, horse, reindeer, stag, ass, wild goat, mammoth and hyena; the horse and bison predominate. There were also engravings done in the clay of the cavern; those above high water are still preserved.

Casteret deserves high praise for the courage and skill exhibited in meeting difficulties. The danger of losing one's way, even where there is no water to wade or swim, would suffice to discourage many. Casteret had not only to swim, but also dared to pass through the neck of a siphon under water; for the ceiling was so low at one place as to be completely submerged. The story of how he alone, in

bathing attire and carrying a candle and matches in a rubber case, swam a subterranean stream for 1,190 meters (ca. 3,900 ft.) to be finally rewarded by his notable discoveries at Montespan, is a striking example of the courage and endurance demanded of those who would wrest from the caverns their subterranean secrets. In this class belong the achievements of Count Begouen and his sons at Tuc and Trois-Frères (Casteret is a student of Count Begouen at Toulouse) and the Abbé Lemozi with the youthful David at the cavern of David in Lot.

In 1922, David, a boy of fourteen, inspired by the discoveries of the Abbé Lemozi at Marcenac, Sainte-Eulalie and Murat, decided to do some exploring on his own account. Armed with a candle and matches, the lad began exploring on his father's own land; he squeezed through an aperture, crept into a small gallery, and after unusual difficulties eventually found himself in another gallery of large dimensions. Much excited by his success, the lad climbed back to sunlight and reported his discovery first to his father and then to the Abbé Lemozi. Within a month the Abbé Lemozi and David found on the walls of the large gallery some forty figures engraved or painted in black and red; bison, mammoths, horse, fish and the human hand. The great gallery is connected with two smaller galleries, one of which contains a beautiful mural figure of a bear; the other contains mural engravings and paintings, bones and fossilized excrement of the bear. Of special significance are the engraved figures of men (ithyphallic) followed by women with prominent pendant breasts. The art in the cavern of David has been referred in part to the Aurignacian and in part to the Magdalenian Epoch.

It can thus be seen that recent discoveries have tended to widen the field of Paleolithic art. Enough is now known to give one a fairly good idea of the cave artist's reaction to the world about him and the reasons for his choosing the models he did. Almost all his models were animals; representations of plants are very rare and those of inanimate objects also rare. An overwhelming majority of the animals were chosen from among the vertebrates, preference being given to mammals that were useful for food and otherwise: the horse, red deer, reindeer, bison, mammoth, etc. Representations of invertebrates, so far as known, can be counted on the fingers of one hand. The fifth example, an ivory coleopter (insect) from the grotte du Coléoptère (Luxembourg), Belgium, has just been reported by J. Hamal-Nandrin. The four examples previously known are all from France: a coleopter of lignite from a cave at Arcy-sur-cure (Yonne), an ivory beetle from Cap Blanc (Dordogne), a ladybug from Laugerie-Basse (Dordogne), and a *Cypraea* shell of ivory from the cave of Pair-non-Pair (Gironde).

THE HISTORICAL BACKGROUND AND SETTING OF THE PHILOSOPHY OF FRANCIS BACON[1]

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I. Introduction

In a paper prepared for the Toronto meeting of the American Association for the Advancement of Science the writer attempted to catalogue the various intellectual influences which combined to bring about the decline of ancient science.[2] It was there suggested that an altogether different set of cultural factors and psychic attitudes was required before any reasonable hope could be entertained of the possible rise of an ardent interest in experimental and observational science. It will be the purpose of this paper briefly to survey the historical factors which conditioned and produced these novel intellectual attitudes and made the era of Francis Bacon one of the most dynamic and interesting in the history of thought, science and culture, thus rendering Bacon's enthusiastic manifesto of the inductive and observational method singularly appropriate to his age, whatever his deficiencies in recognizing certain phases of the scientific achievements of his contemporaries, who were as much less gifted stylistically as they were more talented in the actual work of the scientist.[3]

II. The Scholastic Synthesis

As Bacon's "Novum Organon" was designed to uproot and supplant the "Organon" of Aristotle, our survey of the background of Baconian thought should begin with a brief analysis of the Scholastic method, as systematized by Aquinas, Scotus and Occam, which presented the most perfect embodiment of dialectical technique and skill yet produced by mankind. The Patristic age, profoundly influenced in its intellectual attitudes by Neo-Platonism, had eschewed reason and placed its reliance upon faith, revelation and authority.[4] Perhaps the first important thinker to challenge this view of the all-sufficiency of faith was the most daring mind of the ninth cen-

[1] Paper read at the Cincinnati meeting of the American Association for the Advancement of Science, December 31, 1923.

[2] Published in the *Pedagogical Seminary*, June, 1922.

[3] The best guide for such a survey is J. H. Robinson's "Outline of the History of the Western European Mind," pp. 28–51.

[4] A. Harnack, "History of Dogma," Vol. I, pp. 336 ff.

tury, Erigena, who suggested that in certain cases reason might occupy an important place along with faith in unravelling the mysteries of theological verity. This position was not general, however, at the time, and it brought no little unpopularity and criticism upon its author and sponsor.[5] Much more in the spirit of the age were the edifying encyclopedia of Rhabanus Maurus, embodying accepted tradition as to secular and spiritual truth, and the convenient *Glossae* of scriptural and patristic authorities on various problems of theological import prepared by men like Walafrid Strabo.[6]

This practice of compiling edifying and convenient anthologies of accepted authorities went along very well and seemed adequate for the guidance of the faithful Christian on his itinerary to the New Jerusalem, until, in the early twelfth century, a monk named Peter Abelard brought out a work entitled "Sic et Non," which proved that revealed authority was apparently frail and untrustworthy. He selected certain main problems of philosophy and theology, and then indicated that on all these issues there were fundamental divergences of opinion on the part of the most eminent and reputable of scriptural and patristic authorities. He also launched a vigorous attack upon the Neo-Platonic and Patristic contention that credulity was the mental attitude most befitting a Christian. In what might well be the slogan of every critical and progressive thinker, he denied the efficacy of simple and gullible credulity and passive expectation of revelation, by holding that "the beginning of wisdom is found in doubting; by doubting we come to examine, and by further examination we may come upon the truth." By his subtle dialectic he indicated the power of reason in the face of the futility of discrepant authority and dubious revelation.[7]

After the time of Abelard the question raised by Erigena as to whether reason might not have a place along with faith was an anachronism; it was thenceforth evident enough that faith could no longer rest on authority and revelation alone, but must be buttressed by the most irreproachable logic. Such being the case, it was essential to provide some place in which the defenders and expositors of the faith might be adequately trained for their new requirements and responsibilities. The result was the rise of the medieval universities. The scope and purpose of medieval university instruction is well expressed in the famous medieval phrase that "the sword of God's word is forged by grammar, sharpened

[5] R. L. Poole, "Illustrations of the History of Medieval Thought."

[6] H. O. Taylor, "The Medieval Mind," Chap. X.

[7] J. McCabe, "Abelard"; J. G. Compayré, "Abelard and the Rise of the Universities."

by logic, and burnished by rhetoric, but only theology can use it." While there were universities which offered graduate instruction in law and medicine, theology still remained "the queen of the sciences," though the students of theology were not as numerous as they became after the Counter-Reformation. The work for the bachelor of arts degree was regarded as little more than an academic apprenticeship, and the subjects studied were primarily the trivium, or first triad of the seven liberal arts, consisting of grammar, rhetoric and dialectic. The latter was the most important, however, and it prepared the student to go forward to advanced work in law and medicine as well as theology. It was based primarily upon Aristotle's "Organon" and was the dominant technique of medieval Scholasticism. It rested upon the assumption that the realm of reality was the world of ideas, generally independent of the external world as revealed by sense perception, and that truth could be assuredly surprised and captured when pursued by a strategic ruse founded upon the laws of sound argumentation. Avoidance of logical fallacies in weighing the arguments of the ancients, rather than observation of the commonplace things of nature, was the sure path to determinate truth and the augmentation of wisdom.[8] Francis Bacon himself thus caustically summarized the methodology and achievements of the Scholastic philosophers:[9]

> Having sharp and strong wits, and abundance of leisure, and small variety of reading, but their wits being shut up in the cells of a few authors (chiefly Aristotle their dictator), as their persons were shut up in the cells of monasteries and colleges, and knowing little history, either of nature or time, they did out of no great quantity of matter and infinite agitation of wit spin out unto us those laborious webs of learning which are extant in their books.

The following passage may be spurious, but no one acquainted with medieval learning would regard it as an inaccurate representation of the procedure of the Scholastic age in the settlement of a perplexing problem:

> In the year of our Lord 1432, there arose a grievous quarrel among the brethren over the number of teeth in the mouth of a horse. For thirteen days the disputation raged without ceasing. All the ancient books and chronicles were fetched out, and wonderful and ponderous erudition, such as was never before heard of in this region, was made manifest. At the beginning of the fourteenth day, a youthful friar of goodly bearing asked his learned superiors for permission to add a word, and straightway, to the wonderment of the disputants whose deep wisdom he sore vexed, he beseeched them to unbend in a

[8] C. H. Haskins, "The Rise of Universities"; H. Rashdall, "The Universities of Europe in the Middle Ages"; L. J. Paetow, "The Arts Course in Medieval Universities"; M. DeWolf, "History of Medieval Philosophy."

[9] Cited in J. H. Robinson, "Mind in the Making," p. 122.

manner coarse and unheard of, and to look in the open mouth of a horse and find answer to their questionings. At this, their dignity being grievously hurt, they waxed exceedingly wroth; and joining in a mighty uproar, they flew upon him and smote him hip and thigh, and cast him out forthwith. For, said they, surely Satan hath tempted this bold neophyte to declare unholy and unheard of ways of finding truth contrary to all the teachings of the fathers. After many days more of grievous strife the dove of peace sat on the assembly, and they as one man, declaring the problem to be an everlasting mystery because of a grievous dearth of historical and theological evidence thereof, so ordered the same writ down.

Yet it is easy to be over-critical, supercilious and contemptuous in estimating the intellectual attainments and contributions of the Schoolmen. Considering the cultural and intellectual setting of the time, they were a credit to scholarship and the teaching profession. They aroused a permanent professional interest in teaching, outlined and systematized the knowledge requisite for the profession, perfected the technique of research as that matter was then understood, and generated real enthusiasm on the part of a multitude of students who were compelled to study under far less advantageous conditions than now exist in institutions of higher learning. For the greater part of the intellectual life which existed in the medieval period the scholastic philosophers and pedagogues were responsible, and the superiorities of modern university instruction and scholarly achievement must be assigned primarily to the vast advances in the general cultural and technical setting of modern educational efforts.[10]

III. Progressive Intellectual and Scientific Trends in the Medieval Period

Two other facts which should lead us to take a somewhat more appreciative standpoint towards the Middle Ages than is frequently done are the existence of men whose attitudes were a harbinger of the coming era of observational and experimental science; and the western European appropriation of the learning which the Arabs had absorbed from their contact with late Hellenistic culture and the East, and preserved in part throughout the medieval period. Men like Adelard of Bath, Michael Scot, Albert the Great, Peter of Abano and Witelo were truly scientific in their attitudes and aspirations, and might well have been great laboratory scientists had they lived in the scientific and technical setting of Helmholtz, Pasteur

[10] A fairly judicious estimate is to be found in Taylor, "Medieval Mind," Vol. II, Book VII. The best summary is contained in Haskins, *op. cit.*, chap. ii.

[11] See Lynn Thorndike, "History of Magic and Experimental Science during the First Thirteen Centuries of Our Era"; Vol. II, pp. 14–49, 307–337, 454–456, 517–575, 874–947; and C. H. Haskins, "Studies in the History of Medieval Science."

and Emil Fischer.[11] The venerable illusion that Roger Bacon was the only medieval figure who comprehended or practiced the elements of the observational and inductive method should have been dispelled by the various critical and historical essays which appeared around the year 1914, in conection with the seven hundredth anniversary of Bacon's birth, and is no longer at all tenable in the light of the recently published researches of Professors Lynn Thorndike and C. H. Haskins on the scientific activity of the medieval period.[12] Yet, if Bacon was not unique in regard to his actual achievements in the field of scientific activity, it will probably be conceded by even critical students that he set forth the limitations of the dialectical method, discussed as a methodological abstraction and technique the observational and experimental method, indicated the possible technical and social improvement inhering in the application of science, and classified the leading causes of obstruction to clear and independent thinking more successfully than any other single figure in the Middle Ages. At the same time it is not unfair to point out that his preeminence, if it may be regarded as such, like that of Lord Bacon, consisted more in his superior rhetoric and the more trenchant phraseology of his writings than in substantial practical achievement in scientific activity.[13]

Even more important for the intellectual and scientific progress of Europe were the series of innovations in mathematics and science, and the significant practical inventions which came into western Europe before the close of the Middle Ages, primarily as a result of European contact with Arabic and oriental culture—prophetic, as it were, of the future when the whole character of European civilization was to be transformed from the contact of Europe with extra-European lands. In mathematics the Arabs transmitted to Europe the so-called Arabic numerals, which were probably of Indian origin and facilitated simplified arithmetical calculations which were impossible with Roman numerals, the algebraic notation which allowed Galileo, Descartes, Napier, Newton and Leibnitz to carry on the development of mathematics to the calculus, an achievement denied to Archimedes because of the lack of an adequate notation, and the Greek contributions to geometry which had been largely lost during the early medieval period in western Europe. In optics Alhazen and others carried on the contributions

[12] Thorndike, *op. cit.*, pp. 616–687.

[13] *Ibid.* We have not here assumed to discuss the validity of the so-called Roger Bacon manuscript which, if genuine, would seem to indicate that Bacon anticipated Hooke in the use of the microscope by some four centuries. For a summary of the situation see *Harper's Magazine*, July, 1921, pp. 185–197. For Bacon's contributions to optics see C. Singer, "Studies in the History and Methods of Science," Vol. II, pp. 121 ff.

of Euclid and other Greek workers in this field, executing preliminary achievements in the way of manufacturing lenses and mirrors, which were of indispensable significance for the further development of the sciences like biology and astronomy, which depend upon the utilization of the microscope and telescope, to say nothing of the services rendered to the mitigation of failing eyesight, and the inspection, adornment and possible beautification of the human anatomy. Clocks were developed as far as the principle of the balance clock, possibly from Arabic models, thus initiating the progress which led to the ultimate perfection of the stop-watch and the appearance of reliable dynamic mechanics.[14]

While the Arabic and Christian alchemists did not provide the philosopher's stone and achieve transmutation of metals and personal rejuvenation, they did discover or utilize certain useful chemicals, such as antimony, saltpeter, arsenic, zinc, bismuth, manganese, ether and metallic salts, which furnished the basis for the work of the early chemists from Paracelsus onward, who endeavored to divorce chemistry from the supernaturalism and mysticism of alchemy and to secure its concentration upon practical technical problems. The ultimate outcome of the work of the alchemists thus justified Francis Bacon's notable figure when he said that "alchemy may be compared to the man who told his sons that he had left them gold buried somewhere in his vineyard; while they by digging found no gold, but by turning up the mould about the roots of the vines procured a plentiful vintage. So the search and endeavors to make gold have brought many useful inventions to light."[15] The Arabs also brought to Europe the knowledge of paper-making. The Chinese had probably been the first to manufacture paper, making it out of the pulp of the mulberry tree. The Arabs had substituted cotton-fibre and introduced paper of this type into Spain. The Europeans adapted flax and rags to its manufacture, and paper-making had become relatively common in Europe by the close of the thirteenth century. In this manner the invention of printing by means of movable type in the middle of the fifteenth century was given practical significance through the prior provision of abundant material on which to operate this new technique.[16] Last, but by no means least important, there should be mentioned the mariner's compass, which is first mentioned by an English monk, Alexander Neckham, at the close of the twelfth century. It was the compass, more than any improvement in ship-building, which en-

[14] Sedgwick and Tyler, "A Short History of Science," pp. 156–190.

[15] E. Thorpe, "A History of Chemistry," Vol. I, pp. 28–56.

[16] H. A. Maddox, "Paper: Its History, Sources and Manufacture."

abled Columbus to execute successfully a trans-Atlantic voyage and paved the way for European expansion overseas in the sixteenth and seventeenth centuries—a movement fraught with more consequences for the history of western civilization than any prior development in the history of western Europe.[17]

IV. The Renaissance in Intellectual History

A generation ago it was fashionable to assign great importance to the Renaissance in the development of modern civilization. In the works of the esthete Symonds and the poet Burkhardt one finds the general thesis that the Middle Ages were a period of general and relatively uniform stagnation, the paralyzing shell or envelope of which was burst by the potent forces arising from the new appreciation of classical literature and the remarkable developments of chromatic and plastic art during the two centuries following 1450. The most diverse results of a progressive nature have been assigned to such factors and causes, not even excepting the rise of modern science, the mastery of oceanic navigation, and the rise of the national state system. The results of a generation of historical scholarship have been such as totally to dissipate this illusion. In the first place, we have learned much more about the real nature of the Middle Ages. It has been shown that they can not be dealt with as a unified period, there being an enormous gulf between the culture of Merovingian France and the Italy of Dante. It was not an era of uniform cultural stagnation; particularly from the twelfth century onward there was a steady, if gradual, intellectual and scientific improvement, and the Renaissance, as such, did little to stimulate these tendencies in any unique manner. In the second place, it has been shown that it is manifestly inaccurate and misleading to throw together all the multifarious and diverse cultural developments of the period from 1450 to 1700 and assign them to the Renaissance. If this term is to have any specific meaning whatever it must be held to refer to Humanism and the developments in art. The latter may be left out of this discussion.[18]

As to Humanism it can scarcely be proved that the laudable increase of interest in, and approval of, the literatures of Greece and Rome produced any remarkable intellectual revolution, least of all any marked impulse to renewed scientific curiosity. The only direct contribution which Humanism made to the new science lay

[17] Thorndike, *op. cit.*, Vol. II, pp. 199, 387–388.

[18] J. T. Shotwell, "Middle ages" in Eleventh Edition of the *Encyclopedia Britannica;* J. H. Robinson, "The New History," pp. 154–160; "Petrarch," second edition, Introduction; H. O. Taylor, "Thought and Expression in the Sixteenth Century," Preface and Chap. I; K. Brandi, "Das Werden des Renaissance."

in the recovery and reading of some of the writings of the Greek scientists who had far more modern and acceptable ideas on scientific matters than those of most medieval figures, but instances of this sort were very few and relatively unimportant. The most encyclopedic of all the Greek scientists, Aristotle, had been well known to the Schoolmen in good translations from the Greek from the close of the thirteenth century onward.[19] The Humanists were much more attracted by rhetorical and mystical pagan works than by the scientific treatises of antiquity. Cicero and Neo-Platonic writers loomed far wider on the horizon than Aristarchus, Archimedes or Hipparchus. As Professor Robinson has judiciously said:

> The so-called Renaissance offers nothing comparable to the achievements of the twelfth and thirteenth centuries. It is true that in the fourteenth and fifteenth centuries the Italian towns developed an interesting civilization and a marvelous art different from that which went before. These have perhaps blinded us to the relatively slight contributions of the period to general change. To one who is intent upon establishing the continuity of history the men of letters, the philosophers, and even the artists of the Renaissance, exhibit an extraordinary intellectual conservatism. They transcended relatively few of the ancient superstitions, contributed but little to the knowledge of the world, and readily yielded to the fascination of Neo-Platonic mysticism, as is illustrated by Ficino, Pico and Reuchlin.
>
> As has been said elsewhere, it was quite possible to read the classics without becoming forthwith Hellenic in one's attitude of mind. It may be safely said that as one's acquaintance with the Middle Ages, as well as his appreciation of our own time, increases, the Renaissance seems to grow more and more shadowy as a distinctive period; and yet many writers use the term as if the Renaissance were a bright spirit, hovering over Europe, touching this writer and that painter or architect, and passing by others who were in consequence left in medieval darkness. . . .
>
> It is a grave mistake to assume that this renewed interest in the Greek and Roman authors betokened a revival of Hellenism, as has commonly been supposed. The libraries described by Vespasiano, a Florentine bookseller of the fifteenth century, indicate the least possible discrimination on the part of his patrons. Ficino, the translator of Plato, was an enthusiastic Neo-Platonist, and to Pico della Mirandola the Jewish Caballa seemed to promise infinite enlightenment. In short, *Plato was as incapable in the fifteenth century of producing an intellectual revolution as Aristotle had been in the thirteenth.* With the exception of Valla, whose critical powers were perhaps slightly stimulated by acquaintance with the classics, it must be confessed that there was little in the so-called "new learning" to generate anything approaching an era of criticism. It is difficult, to be sure, to imagine a Macchiavelli or an Erasmus in the thirteenth century, but it is likewise difficult to determine the numerous and subtle changes which made them possible at the opening of the sixteenth; and it is reckless to assume that the Humanists were chiefly responsible for these changes.[20]

[19] E. Emerton, "Beginnings of Modern Europe," Chap. ix–x; H. O. Taylor, "Thought and Expression in the Sixteenth Century," Book I.

[20] J. H. Robinson, "The New History," pp. 116–117, 157–158.

The most significant and potent impulse given by Humanism to intellectual and scientific advance was an indirect one, consisting in a revival of interest in the things of this world. The intellectual classes among the pagans, by contrast with the Christians, had been singularly little interested in the supernatural world or the destiny of the soul. They were primarily concerned about the most happy, adequate and efficient type of life here on earth. Philosophy was designed to teach how to live successfully rather than how to die with assurance of ultimate safety in the arms of Jesus. This dominant secular interest had been lost for approximately a millennium on account of the Christian absorption in the problems and technique of the salvation of immortal souls, and Augustine himself had warned against becoming too much engrossed in earthly interests lest assurance of successful entry into the New Jerusalem be jeopardized. As men like Petrarch and his followers and successors came to read more of pagan literature and to approve it heartily, they were inevitably infected with the virus of the secular orientation of the Greek and Roman past, and there arose the amusing situation of actually pious Humanists enthusiastically recommending what was frankly branded by Augustine as an undoubted and integral portion of the City of the Devil.[21] Erasmus admitted that the appellations St. Socrates and St. Cicero were neither inaccurate nor inappropriate and sacrilegious. He thus openly expressed his preference for pagan writers when compared with even the most illustrious Schoolmen:[22]

> Whosoever is pious and conduces to good manners ought not to be called profane. The first place must indeed be given to the authority of the Scriptures; but, nevertheless, I sometimes find things said or written by the ancients, nay, even by the heathens, nay, by the poets themselves, so chastely, so holily, and so divinely, that I can not persuade myself but that, when they wrote them, they were divinely inspired, and perhaps the spirit of Christ diffuses itself farther than we imagine; and that there are more saints than we have in our catalogue. To confess freely among friends, I can't read Cicero on "Old Age," on "Friendship," his "Offices," or his "Tusculan Questions" without kissing the book, without veneration towards that divine soul. And, on the contrary, when I read some of our modern authors, treating of politics, economics and ethics, good God! how cold they are in comparison with these! Nay, how do they seem to be insensible of what they write themselves. So that I had rather lose Scotus and twenty more such as he (fancy twenty subtle doctors!) than one Cicero or Plutarch. Not that I am wholly against them either; but because, by the reading of the one, I find myself become better, whereas I rise from the other, I know not how coldly affected to virtue, but most violently inclined to cavil and contention.

That the generation of an interest in the secular world was an

[21] E. M. Hulme, "Renaissance and Reformation," Chaps. i–xi; P. Monroe, "Textbook in the History of Education," Chap. vi.

[22] K. Pearson, "The Ethic of Free Thought," pp. 165–166.

impulse in the direction of scientific curiosity, as compared with the supernaturalism and eschatology of Patristic and Scholastic Christianity, can not be denied, yet it was but a feeble and indirect urge, which was probably far more than offset by the anti-scientific tendencies of the Humanistic movement in education. This is still extant and well reflected by the notion that a college student majoring in physics, chemistry or biology can make no claim to any true education and culture as compared with one who has shown proficiency in wrestling with the ablative absolute, hortatory subjunctive or future periphrastic, and should, accordingly, have his barbarism properly stigmatized by the degree of bachelor of science. It was the mystical and esthetic, rather than the scientific and rationalistic, attitude which was promoted by the spirit of Humanism, and at its very best it could do no more than to produce the learning of a Scaliger or Casaubon or the broad-minded tolerance of a Montaigne. Humanism could no more produce the modern world than the Greek and Roman culture upon which it was based. And, finally, what slight indirect impulse Humanism may have given to secular studies and science was obstructed or frustrated by the revival of supernaturalism and bigotry in the period of the Reformation and Counter-Reformation. By the time scholarship had recovered from this blow, the explorers and scientists had created a new world of fact and ideas quite foreign to Erasmus, Luther, Baronius and Loyola alike.[28]

The invention of printing, which came as a result of the labors of Coster and Gutenberg in the period of Humanism, was a very important contribution to the ultimate development of a technique which is so much a thing of cooperative effort and effective communication as modern science, but here again the service was indirect and incidental rather than causal. There was no immediate flood of radical or scientific books. The majority of the books printed during the first century or so after Gutenberg were not scientific and critical works but pious religious and theological books, usually a reproduction of those which had appeared in the centuries before the invention of printing as a result of the patient and persistent efforts of medieval copyists in the monastic *scriptorium*. It was not until the sixteenth and seventeenth centuries that books reflecting the beginnings of the new thought and science were printed in any considerable number. Neither did printing make it easier to produce progressive books. The European governments made unlicensed printing a serious offense, in some states

[28] Preserved Smith, "The Age of the Reformation," Chap. i; "Erasmus," Chaps. ix, xii, xv; E. Feuter, "L'Histoire de l'Historiographie Moderne," Livre I.

a capital crime, and established a thorough censorship of the licensed presses. The precarious nature of the printing profession in regard to the issuance of novel scientific or philosophical works is well illustrated by Osiander's famous preface to Copernicus' work, in which Osiander, to protect his press, implied that probably Copernicus was only joking. To-day this sort of censorship functions chiefly as regards text-books.[24]

V. The Place of the Reformation in European Intellectual History

Even less than the Renaissance did the Reformation and Counter-Reformation directly promote a scientific and critical point of view or encourage interest in mundane and secular affairs. It has been assumed by many that the Renaissance produced the Reformation, but it seems that this is true only in the sense of a somewhat ironical remark once made by Professor Robinson to the effect that the mythical Renaissance may have caused the mythical Reformation. Between Humanism and Protestantism there was little real intellectual affinity or genetic relationship, however much there may have been of personal identity and interrelationship between Humanists and Reformers. If any of the Protestant reformers derived inspiration from the Humanists, it was from the piety and Christianity of the scholars and not from their Humanism. If Luther was impelled to ecclesiastical and doctrinal reform by his study of Erasmus' writings, it was due to the ideas of Erasmus the Christian and not to those of Erasmus the Humanist. The exuberance of Erasmus over the writings and doctrines of Saint Cicero could never have been the starting point for the theological views and intellectual attitudes of a Luther, a Calvin, a Knox or a Jonathan Edwards. Cicero's beautiful little motto, which might appropriately serve as the starting-point for tolerant thinkers in all ages, "We who search for hypotheses are prepared both to refute without prejudice and to be contradicted without resentment," could hardly have been the fountain-spring from whence Calvin derived his canons of hospitality, as exemplified in his treatment of Servetus after their little friendly tilt over the nature of the Trinity.[25]

The important point is that, strictly speaking, Humanism, on the one hand, and Lutheranism and Calvinism, on the other, were

[24] Smith, "Age of the Reformation," pp. 8–10, 418–424; J. H. Robinson, "Mind in the Making," pp. 10–11; "The Humanizing of Knowledge," pp. 64–69.

[25] J. B. Bury, "History of the Freedom of Thought," Chap. iv; K. Pearson, "Ethic of Free Thought," Chaps. viii–ix.

fundamentally divergent and opposed. Humanism was a moderate and rather unconscious revolt against the supernaturalism and other-worldliness of Patristic and Scholastic Christianity; the Protestant revolt brought with it an all-pervading revival of even the grosser forms of supernaturalism, diabolism, miracle-mongering, witchcraft and a host of other phases of this general cultural complex. Even some of the Protestant protests against certain symptoms of alleged worldliness in the Catholic Church of the early fifteenth century may be regarded as of dubious validity, when viewed from a strictly historical, scientific and secular standpoint. In short, Humanism and the Reformation were highly divergent in general cultural orientation and intellectual outlook, and we may agree with Erasmus that if Luther hatched the egg which he (Erasmus) had laid, it was quite a different bird from what Erasmus had intended. Professor Preserved Smith's criticism of Karl Pearson's lack of superior and definitive erudition on such matters as the Renaissance and Reformation is undoubtedly justifiable, but it seems that Pearson stumbled on materials which have led him to formulate exactly the correct interpretation of the divergent viewpoints of Erasmus and Luther in the famous chapters of his "Ethic of Free Thought."[26]

Some Protestants have taken great pride in the elimination of many alleged idolatrous practices of the Catholics which was effected by the Reformation, but their exultation rests upon dubious foundations. By doing so they enormously weakened the emotional power of the church and took from it one of its most potent forces and appeals in visual and oracular imagery. The rich emotion-bearing ritual and liturgy of the Catholic church is far better adapted to attracting and holding the mass of faithful believers than the metaphysical dogmatism of Calvin or the savage vocal emotionalism of our evangelical Protestant cults. The intellectual classes, who were once attracted by the Calvinistic metaphysic, have now generally discarded all types of orthodoxy, and it may well be that the heroic evangelistic gymnastics of Billy Sunday and his kind are required to fill up the depleted ranks of Protestantism chiefly because of the fatal strategy of the leaders of early Protestantism in giving up most of the impressive Catholic ceremonial of worship. And no candid critical observer is likely to regard the miracle of the mass and its attendant ritual, or images of Jesus, the Virgin and the Saints, as more or less pagan and idolatrous than baptism, or various phases of Protestant theology which have a definite Greek basis. Probably no one has more sagaciously

[26] Preserved Smith, "Erasmus," pp. 433–434; Pearson, *op. cit.*; C. Beard, "The Reformation in its Relation to Modern Thought and Culture."

summarized the necessary and desirable qualifications upon exuberance over the progressive intellectual tone of Protestantism than Professor Robinson.[27]

The defection of the Protestants from the Roman Catholic Church is not connected with any decisive intellectual revision. Such ardent emphasis has been constantly placed upon the differences between Protestantism and Catholicism by representatives of both parties that the close intellectual resemblance of the two systems, indeed their identity in nine parts out of ten, has tended to escape us. The early Protestants, of course, accepted, as did the Catholics, the whole patristic outlook on the world; their historical perspective was similar, their notions of the origin of man, of the Bible, with its types, prophecies and miracles, of heaven and hell, of demons and angels, are all identical. To the early Protestants, as to Catholics, he who would be saved must accept the doctrine of the triune God and must be ever on his guard against the whisperings of reason and the innovations suggested by scientific advance. Luther and Melanchton denounced Copernicus in the name of the Bible. Melanchton re-edited, with enthusiastic approval, Ptolemy's astrology. Luther made repeated and bitter attacks upon reason; in whose eyes he freely confessed the presuppositions of Christianity to be absurd. Calvin gloried in man's initial and inherent moral impotency; and the doctrine of predestination seemed calculated to paralyze all human effort.

The Protestants did not know any more about nature than their Catholic enemies; they were just as completely victimized by the demonology of witchcraft. The Protestant revolt was not begotten of added scientific knowledge, nor did it owe its success to any considerable confidence in criticism. As Gibbon pointed out, the loss of one conspicuous mystery, that of transubstantiation—"was amply compensated by the stupendous doctrines of original sin, redemption, faith, grace and predestination" which the Protestants strained from the epistles of St. Paul. Early Protestantism is, from an intellectual standpoint, essentially a phase of medieval religious history.

Without attempting in any way to pass judgment upon the theological merits or validity of the positions taken by Protestant reformers, it may be pointed out that the majority of historians have now accepted the view that the great significance of the Reformation lay in the political and economic movements associated with it, rather than in the purely religious and theological problems and issues involved. In line with the suggestions made long ago by Sleidanus and Harrington, contemporary writers like James Harvey Robinson and Max Weber have shown that the most vital phases of the Reformation period were the rise of the independent sovereign states and the ideals and practices of the modern *bourgeois* business man, which God was supposed to have initiated and to have given his unqualified approval.[28]

[27] J. H. Robinson, "The New History," pp. 117–118.

[28] J. H. Robinson, "The study of the Lutheran revolt," in *American Historical Review*, January, 1903; J. H. Robinson, article "Reformation," in Eleventh Edition of the *Encyclopedia Britannica*; M. Weber, "Die Protestantische Ethik und der Geist des Kapitalismus," in *Archiv für Sozialwissenschaft und Sozialpolitik*, 1905; Smith, "Age of the Reformation," Chap. xiv; R. H. Tawney, "Sixteenth century religious thought," in *Journal of Political Economy*, 1923.

Intellectually speaking, the Reformation was most decidedly backward-looking. Theologically it assumed to go back to the Apostolic age. Luther denounced the universities, designated reason as the devil's most seductive harlot whose neck faith could easily wring, revelled in devil and miracle-mongering, and was the first important European to condemn the Copernican theory, his grounds being that the theory was preposterous in the light of the fact that "in the day when Jehovah delivered up the Amorites before the children of Israel Joshua said in the sight of Israel, 'Sun, stand thou still upon Gibeon,' and the sun stood still and the moon stayed until the nation avenged themselves of their enemies." The Calvinistic anthropology, with its morbid basis in the concept of human treason before God, and his predestinarian theology, were alike intellectually depressing and abhorrent. And no person could be less sympathetic with science and critical philosophy than a fanatic like Knox. Then, the Protestant emphasis on the infallible nature of the Bible was in some ways more dangerous and obstructive to progressive thought and scientific advance than the Catholic dogma of an infallible Church which might periodically alter its tenets. The Protestants might be more readily forgiven for their Bibliolatry if they had evidenced a major concern with the teachings of Christ, but instead they revived an interest in, and primary emphasis on, the Old Testament, with all its savagery and anachronisms, which served well as a basis for the Sabbatarian excesses of the Puritans.[29]

About the only contribution to intellectual progress which can be assigned to Protestantism is the indirect aid which it gave to the growing difficulty in ecclesiastical repression of the freedom of thought and expression. This was foreseen and deplored by Bossuet. As he clearly pointed out, once the unity of Christendom had been broken by the Protestants, there was no reason why the process should not go on indefinitely and lead to the multiplication of innumerable Protestant sects, thus making it impossible to enforce any unity of doctrine. It was in this matter of rendering ecclesiastical interference with thought less easy and effective, through promoting the disunity of Christian belief and organization, that Protestantism aided, if at all, in advancing intellectual progress. In a minor sense Calvinism, with its emphasis on the God-given calling of money-making, may be said to have promoted the fostering of those phases of applied science that have been closely related to modern industry and the practical applications of the "theory of business enterprise."[30]

[29] Pearson, *op. cit.*, Chap. ix; Smith, "Age of the Reformation," Chaps. xii–xiii; A. C. McGiffert, "Protestant Thought before Kant," Chaps. i–v.

[30] Fueter, *op. cit.*, pp. 329–331; E. Gibbon, "Decline and Fall of the Roman Empire," Chap. liv; R. H. Tawney, *loc. cit.*

The reaction of the Protestant revolt on Catholicism was intellectually more disastrous than its effect upon the followers of Luther and Calvin. The cultural degradation which came with the Catholic defence-reaction in the Counter-Reformation can best be gauged and measured by the contrast between a typical pre-Reformation Catholic like Erasmus and the most characteristic figure in Counter-Reformation Catholicism, Ignatius Loyola. While no movement founded by an Erasmus could have produced a Voltaire, as the most cursory comparison of the "Adages" with the "Philosophical Dictionary" will readily demonstrate, neither would it have naturally led to the creation of the Jesuit Order. The church had been growing more tolerant and more appreciative of secular learning, when it was put on the defensive by the Protestant assaults and felt it necessary to recover, revivify and defend vigorously monstrous dogmas which had been partially allowed to lapse, and to defend as grotesque and repellant a supernaturalism as that propounded by any Protestant fanatic.[31] Protestantism and Counter-Reformation Catholicism collaborated in producing and enacting the most degrading and depressing drama in the history of western civilization—the witchcraft mania and delusion of the sixteenth and seventeenth centuries. It is a pleasant task to turn from this abysmal culmination of the revival of supernaturalism in early modern times to the parallel and synchronous achievements of the scientists who were discovering a new heaven and a new earth.[32]

VI. The Discovery of the New Heavens and the New Earth

If neither the Renaissance nor the Reformation can well be regarded as forward-looking or progressive movements which notably aided in producing the modern scientific and critical outlook, the adequate and potent causes for the origins of modern times can be located in the rise of modern science and the expansion of Europe overseas, with the many and varied results which came from this process.[33]

It is futile to attempt to discover or assign any specific cause for the *rise* of modern science; in fact, it is probably inaccurate to use that term, for modern science was not a sudden development but a gradual growth from the time of Gerbert onward. The new knowledge from the east, the new intellectual life promoted by

[31] Smith, "Age of the Reformation," Chap. viii.

[32] Smith, *op. cit.*, pp. 651–661; W. E. H. Lecky, "The Rise and Influence of Rationalism in Europe," Chap. i; C. Singer, "Studies in the History and Methods of Science," I, pp. 189–224; J. M. Robertson, "A Short History of Free Thought."

[33] J. R. Seeley, "The Expansion of England," Book I, Lecture v.

the rise of the towns and universities, the overseas explorations and discoveries, and the cumulative ferment and knowledge from these sources, all combined to bring about the remarkable outburst of scientific activity and achievement of the sixteenth and seventeenth centuries. In general, the whole movement was, consciously or unconsciously, a revolt against the deductive method and spiritual objective of Scholasticism—a conviction that the new body of saving knowledge was to be found through an observation of nature, and that in this procedure the Scholastic technique was impotent because, as Bacon himself expressed it, "Nature is more subtle than any argument."[34]

Perhaps one major reason why the first remarkable results of early modern science were so impressive was the fact that it was directed towards a majestic and imposing problem and objective—an investigation of the nature and movement of the heavenly bodies. Few would claim that Kepler and Galileo were greater scientists than Huygens and Leeuwenhoek, but the field of their labors was one designed to give their results a more compelling interest and widespread wonder and admiration. It should be remembered, of course, that while the Schoolmen had accepted it and Dante had immortalized it in his *Commedia,* the cosmology of the early sixteenth century was not a Christian but a pagan product. The Scriptural cosmology was one which represented the earth as a minute slab of earth and water supported on the void and lighted with heavenly bodies of varied candle-power which studded the canopy of the heavens at no great distance from the earth—a system similar to that to-day taught in the schools of Zion City where Voliva gives proof of greater astronomic literalness and piety than was exhibited by the learned Aquinas and the poet Dante. One is moved to an ironical smile when he contemplates the fear of Copernicus, the persecution of Galileo, and the martyrdom of Bruno at the hands of Christians for uprooting a wholly pagan cosmology and theory of celestial mechanics.[35]

Copernicus did little to modify the Hellenic celestial mechanics which had been accepted by Christendom beyond exchanging the positions of the sun and the earth in the vast and complicated arrangement of fixed crystalline spheres, thus transforming it from a geocentric to a heliocentric system. But Giordano Bruno perceived clearly the implications of the shift from a geocentric to a heliocentric universe and set them forth with impressive clarity and comprehensiveness. Among his hypotheses damaging to the

[34] Smith, *op. cit.,* pp. 609–624; C. Seignobos, "History of Medieval and Modern Civilization," Chap. xvii.

[35] Singer, *op. cit.,* Vol. I, p. 31.

cosmology of the Christian Epic were such things as the infinite size of the universe, the lack of finite limitations on, or a fixed center for, the universe, the fallacy of the doctrine of the rigid crystalline spheres, with the substitute conception of the free motion of the heavenly bodies in space, the relativity of space, time and motion, the ever-changing positions and relations of the heavenly bodies, the similarity or identity of the constituent materials in the heavenly and earthly bodies, and, above all, the particularly disconcerting concept of the plurality of worlds. When to these challenging innovations in cosmic philosophy was added a tendency towards the popularization of such doctrines it is not hard to understand why the Catholic church of the post Counter-Reformation type interfered and arranged the speedy translation of Bruno. Most of his views were at the time pure guess-work, but all have been confirmed by the subsequent developments of celestial mechanics and astrophysics and chemistry.[36]

The succession of figures who laid the definitive basis for the celestial mechanics which held the field largely unchallenged until the era of Einstein consists of Tycho Brahe, Kepler, Galileo and Newton. Tycho Brahe, quite in the spirit of old Hipparchus, carried on a careful study of the heavens and gathered concrete data of great value for later theorists. The first of these was his assistant, Johannes Kepler, who showed that the planets moved in elliptical paths rather than circular, that they travelled most rapidly when nearest the sun, and that there was a fixed relation between the cubes of their distance from the sun and the squares of their times of revolution. Galileo founded dynamic mechanics by his famous law of falling bodies, which he arrived at as a result of a classic example of experimental science, an achievement so significant that Bergson is said to have remarked that modern science came down from Heaven along Galileo's incline-plane. Isaac Newton, a half century after Bacon's age, combined Kepler's third law with Galileo's law of falling-bodies in his famous law of inverse squares or universal gravitation, which was not only the crowning achievement of seventeenth century science, but the inspiration for much of the liberal philosophy and theology of the eighteenth century. The old heavens, not merely of Genesis and the astrologers, but of Aristotle and Ptolemy, had been wiped away and a new cosmos of infinite expanse and complexity had been substituted, and it is very curious that pious theologians have not understood that this new astronomy was far more of a challenge to the fundamental tenets of the Christian Epic than the Darwinian

[36] G. Forbes, "A History of Astronomy," pp. 30–39; D. Stimson, "The Gradual Acceptance of the Copernican Theory of the Universe"; W. Boulting, "Giordano Bruno."

theory of evolution.[37] The remarkable development of science in the seventeenth century, which has been so well described by Professor Shipley, came for the most part after Bacon had been gathered to his fathers, but the stage was set for it by the achievements and impulse of Kepler and Galileo, of which it was a natural outgrowth.[38]

Even more significant in creating the modern age were the varied cultural results of the expansion of European civilization overseas and the reaction of this process upon European life and institutions. Cultural historians and anthropologists have long recognized that the contact of cultures is far and away the most potent force in breaking down cultural stagnation and provincialism—in other words, the most dynamic factor in history. This all-important progressive force had earlier manifested itself during the period of the Crusades with certain results noted above, and had not failed to maintain itself as an important factor in European history from that time onward, but the era of its greatest potency followed the successful voyages of Columbus and Vasco da Gama. The elucidation of this set of historic influences, which has been the work of historians from Raynal to W. R. Shepherd, has been probably the most important contribution which historians have made to the subject of the setting of the work of both Francis Bacon and early modern scientists.[39]

First and foremost among the forces and impulses coming from European expansion should be put the general disintegration of the medieval and feudal system, and the substitution of a generally novel social and political system, in short, the actual transformation of the whole face of European civilization through the stimulation of the spirit of adventure, scientific curiosity, new knowledge, the rise of world commerce and large scale oversea colonization, modern capitalism and capitalistic institutions, the increase of urban life, the rise of the middle class, and the gradual extinction of the feudal system to be supplanted by the national state, first on a dynastic and absolutistic basis, and later on a representative and parliamentary foundation. In cooperation with

[37] Sedgwick and Tyler, *op. cit.*, Chap. x; H. Höffding, "History of Modern Philosophy," Vol. I, pp. 103–183; H. O. Taylor, "Thought and Expression in the Sixteenth Century," Vol. II, Chap. xxiii; A. D. White, "History of the Warfare of Science and Theology," Vol. I, Chaps. iii–iv.

[38] Sedgwick and Tyler, *op. cit.*, Chaps. xi–xiii; A. E. Shipley, "The Revival of Science in the Seventeenth Century."

[39] W. R. Shepherd, "The expansion of Europe," in *Political Science Quarterly*, 1919; and Unpublished Lectures on the Expansion of Europe; W. C. Abbott, "The Expansion of Europe"; E. Feuter, *op. cit.*, pp. 361–380, 434–449, 475–483.

the Protestant *Ethik* it altered the attitude of religion towards economic practices by eliminating the social point of view and stressing the sanction and approval of God for the ultra-individualism of modern capitalism, with its emphasis upon pecuniary profit as the most pleasing of all achievements in the sight of God. It was this great series of interrelated transformations that laid the basis for the Industrial Revolution and the exploitation of modern sciences and technology which has produced contemporary civilization.[40]

In its specific contributions to science the expansion of Europe was by no means unimportant or negligible. Most directly influenced was the science of navigation, with its accessory sciences of mathematics, engineering and optics. The explorations and discoveries not only enormously increased the concrete geographic information of every type, but stimulated scientific cartography upon the basis of determinable latitude and longitude. Astronomy was enriched by the discovery and observation of constellations in the southern hemisphere, and by the scrutiny of hitherto known heavenly bodies from new positions on the earth's surface. Additions were made to chemical knowledge by the discovery in oversea areas of rocks and minerals of new and significant types. Botany, the materia medica and zoology were remarkably aided and advanced by the great variety and number of newly discovered forms of plant and animal life. And a strong if not adequate stimulus was given to the movement which ultimately founded the science of man or anthropology through the contact with a large number of new racial and sub-racial types in widely different degrees of cultural development. With the equally marked influence of the results of the expansion of Europe on art, literature and currents of thought this is not the place to deal. It is worth pointing out, however, that it did much to stimulate that appreciation of diversity and relativity which loomed large in Baconian thought as compared with that of Aquinas. It is evident that this movement, as a whole, produced a new earth in two important senses; in the first place, by discovering the western and southern hemispheres, and, in the second place, by changing the cultural complexion of the world that had been known before 1500. It is doubly significant for the scientist, in that it not only stimulated many phases of modern science, but also did much to create that contemporary intellectual, economic and social world in which present-day science can function.[41]

[40] A. F. Pollard, "Factors in Modern History"; W. Cunningham, "Western Civilization," Vol. II; J. E. Gillespie, "The Influence of Oversea Expansion on England"; C. J. H. Hayes, "Political and Social History of Modern Europe," Vol. I; Tawney, *loc. cit.*; W. J. Ashley, "Economic History of England," Vol. II, pp. 456 ff.

[41] E. R. Turner, "Europe, 1450–1789," Chaps. v–xxiv; Gillespie, *op. cit.*, Chaps. viii–ix; T. Veblen, "The Place of Science in Modern Civilization."

Such, then, was the world into which Bacon was born. With the possible exception of the fifty years from 1875 to 1925, there has not been a more interesting or crucial period than the half century from 1575 to 1625, in which Bacon passed the productive period of his life. It was the era which carried natural science from Copernicus and Vesalius to Galileo, Napier and Harvey, and prepared the way for the magnificent achievements in the next half century associated with such names as Newton, Huygens, Swammerdam, Boyle, Leibnitz and their contemporaries. In historic conditions at large the first permanent settlements were being made in the New World and the stage was set for those interactions between the Old and New World that have been a leading factor in both cultural and political history from that day to this, and are in a humble but fitting way represented by this occasion.[42]

As to the problem of Bacon's place in the civilization of his day and the degree to which he showed himself aware or appreciative of the scientific methods and achievements of his age, these are matters which may be left to the more competent and better informed authorities who will follow me on this program. On the one side are the extreme partisans of Bacon who look upon him as the real founder of the inductive and experimental method, whose writings have been the point of departure for all the subsequent workers in the scientific field. On the other side are John William Draper and others who take his position, namely, that Bacon was a cheap charlatan who was neither able to make any contributions to science himself nor to appreciate the work of contemporary scientists. Obviously, the truth falls somewhere between these two extremes. It is well known that Bacon failed to appreciate the work of men like Copernicus and Galileo, he certainly was not great as a technical scientist, and it is doubtful if he ever had much direct concrete influence upon specific scientists in their laboratory or observational work, beyond the fact that his "New Atlantis" was the model on which the Royal Society was constructed. At the same time, he rendered a great service in putting his matchless rhetoric at the service of the inductive and experimental method, and in giving the newer method of approaching the problems of knowledge some general currency among educated classes. To fix in the minds of the intellectual class of his age the fundamental thesis that "Nature is more subtle than any argument," thereby branding for all time as inadequate the Aristotelian technique which had been elaborated and relied upon by the Schoolmen, was a real contribution. As deadly as his attack upon the dialectical technique of the medievals was his assault upon the subservience of the faithful to

[42] F. S. Marvin, "The Living Past," Chap. viii.

authority and tradition. By showing that, all other things being equal, every generation is manifestly wiser than its predecessor, as far as the cultural heritage is concerned, and by representing anachronistic authority as the most likely and prevalent form of Satanic manifestation, he showed faith and credulity to be even less trustworthy than "reason."[43]

So, it seems to me, that we shall go far astray if we seek in Bacon the Einstein, the Karl Pearson, the J. Arthur Thomson, the Bergson or the John Dewey of the first quarter of the seventeenth century, but I believe that we shall be on the right track if we attempt to see in him the James Harvey Robinson of his age. In his effort to create a respect for critical and scientific ways of thinking and to improve the lot of mankind thereby, he was the most potent worker of his age in the cause of creating an interest in the process of the making of our minds and in the humanizing of knowledge. Mr. Taylor has briefly but clearly summarized Bacon's contribution, when viewed from this angle:[44]

> He was a great influence in his time and after, spurring men to independent thinking. He urged them to study nature and make experiments and hold fast to facts; and likewise to practical purposes. With many others he protested against subservience to authority; in language and imagery not to be forgotten he showed the Idola, the fetishes, the aberrances and pitfalls of human reason; he set forth a method of induction which, whether practicable or not, might tend to guard men against rashly drawn conclusions. And above all, with intellectual enthusiasm, he urged men on, proclaiming the sure and far-reaching powers of the mind for the attainment of serviceable truth.

[43] See the judicious summary in Taylor, *op. cit.*, Vol. II, pp. 355–372.

[44] Taylor, *op. cit.*, Vol. II, p. 372. For Bacon's interesting plea for intellectual history, see Robinson, "The New History," p. 101.

ENDOWMENT, MATURITY AND TRAINING AS FACTORS IN INTELLIGENCE SCORES[1]

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As my hearers well know, the past few years have witnessed an unusual interest not only on the part of psychologists and educators but also on the part of sociologists, publicists and many well-informed laymen as well, in the theory lying behind the construction of intelligence tests and more particularly in the interpretation of the results secured by their use. An excellent illustration of this unusual interest is afforded by the controversy precipitated by Mr. Lippmann's series of articles in the *New Republic* and by Dr. Bagley's address at Chicago before the Society of College Teachers of Education—which has led to pronouncements by Dr. Terman, Dr. Yerkes, Dr. Thorndike, and to which the present speaker alluded at length in his address as retiring vice-president of Section Q at the Boston meeting of this association. The fact that those immediately concerned in the construction and use of intelligence tests are fully alive to the problems raised and the difficulties presented in this field is also well attested by the tone and spirit of the series of articles by Thorndike, Colvin, Pintner, Miller, Trabue, Rugg and others in the Twenty-First Yearbook of the National Society for the Study of Education on "The general principles of intelligence tests and their administrative use," issued in 1922. The ready sale of this volume and of similar treatises on intelligence tests and their applications shows the interest of schoolmen in the topic, and the critical and controversial reviews that have appeared of such interpretations of intelligence testing as Goddard's "Human Efficiency and Levels of Intelligence" and Brigham's "A Study of American Intelligence" show the concern that is felt by many thoughtful writers in the implications of the movement in question.

I take it that the papers read to-day have been asked for because of the situation just described. It is felt that it would be well for psychologists to review here certain of the more technical issues that have risen and to indicate, if possible, the nature of their ultimate solution.

Before stating what seem to me to be the issues of special im-

[1] Read before Section I, American Association for the Advancement of Science, Cincinnati, December, 1923.

portance in connection with the topic assigned, I would like to recite a sort of *Credo* which, I think, will contain a series of beliefs to which practically all of us are willing to subscribe. Dr. Freeman has done the same sort of thing in his "Referendum of psychologists" in the December, 1923, issue of the *Century Magazine*. Perhaps I may be pardoned for paraphrasing some of Dr. Freeman's statements in view of the fact that I was one of those whose views were solicited for his referendum.

(1) I believe that, while definitions of general intelligence given by the devisers of tests vary in detail (see the symposium on "Intelligence and its measurement" in the *Journal of Educational Psychology,* March and April, 1921), they may be substantially brought into agreement with the phrase: "ability to learn," "to profit by experience"—not merely to learn in the sense of memorizing, then, but ability to assimilate, to coordinate and subordinate items of fact, to appraise them and utilize them in further thinking, especially in prevision, in anticipating the outcomes of situations, both real and imaginary.

(2) I believe that there would be substantial agreement, furthermore, that the forms of intelligence tests now commonly in use put special stress upon that phase of learning that deals with verbal content, with the more abstract, as distinguished from the concrete aspects, of learning; in short, with that aspect of learning that is of primary importance for success in the school.

(3) I believe that intelligence tests as now constructed and operated form the best single device that we possess for measuring this aspect of intelligence. They have gained the highly important pragmatic sanction that they work. Properly administered and interpreted, they provide a prediction of school success which exceeds in validity such other predictive criteria as school marks, teachers' estimates, previous school history, and the like.

(4) I believe that one of the main reasons why this high degree of practical serviceability has been attained is the fact that the makers of the tests have proceeded methodically; that they have invariably sought to standardize their instructions, their material and their statistical methods of handling the results.

(5) I believe that no intelligence tester can lay claim, and so far as I know, none has laid claim, to measure *all* the significant elements of the individual personality. Every maker of tests will agree that conative and emotional aspects of mental activity which are of the greatest significance for daily life remain practically untouched by the stock intelligence tests, and will agree that special forms of mental tests which will yield information concerning these other aspects of personality are greatly to be desired.

(6) More than this, I believe that no intelligence tester has laid claim even to measure all the significant aspects of intellectual endowment in the individual personality. For example, numerous special aptitudes, like the aptitude for music, for mechanical pursuits, for drawing, for dramatics, for appreciating and meeting social situations of all sorts, are untouched. We do not even secure by the general intelligence test any adequate and thorough-going measure of any single aspect of that intelligence: we do not, for instance, secure a complete inventory of the subject's reproductive or recognitory memory, of his range of apprehension in all the possible modalities, of his discriminative sensitivity, of his capacity for continuous constructive thinking on a complex topic, of his sanity of judgment when issues are complex or clouded by bias and partisanship.

(7) I believe that every maker of tests of general intelligence readily admits that he measures that capacity indirectly. We seek to determine the individual's intrinsic capacity by the efficiency he displays in the intellectual performances we demand of him; in short, we estimate what he could do by what he does do.

(8) I believe we all agree that what the examinee does do in a given test is obviously a net resultant of several factors, among which may be mentioned his attitude toward the examiner and toward the examination, his zeal, his general physical condition, his native intellectual capacity, his stage of maturity, and the extent and character of his training (including the sum of the environmental forces that have contributed to the making of his general mental equipment, and more especially those aspects of his training equipment that the particular tasks of the particular examination bring into play).

(9) I believe that the extent to which test results are vitiated by the first few of these factors—the examinee's attitude toward the examination, his zeal and his general physical condition—is usually much exaggerated in the popular mind. Experience shows that a skilful examiner can almost always secure proper cooperation and the output of a reasonable amount of zealous effort. Experience also shows that general physical condition plays comparatively little part in determining such wide differences of score as are actually obtained in most comparative tests.

These nine statements of my *Credo,* then, represent what I believe are nine points of agreement concerning the theory of intelligence testing. I pass now to more debatable issues, to those concerned with the extent to which the remaining factors contribute to the typical intelligence test score. I shall leave out of consideration the factor race and for the moment the factor sex and shall make use especially of three terms to describe the other factors under discussion—namely, endowment, maturity and training.

Definitions of the Factors Endowment, Maturity and Training

By *endowment* I shall mean the innate, constitutional quantum of general intellectual capacity. This I conceive to be substantially given at birth by inheritance. It is the distinguishing element of intellectual efficiency, the factor that makes the individual different fundamentally from other individuals in intellectual grasp. Whether it is biologically a unit character or the resultant of numerous unit characters is not pertinent to this discussion. The extremes of this quantum are typified in the idiot and in the highly gifted (or perhaps in the genius).

By *maturity* I shall mean that stage of development, that degree of unfolding, of this constitutional intellectual endowment which has been attained by virtue of the ripening of the individual's general mental efficiency brought about by the mere passage of time. If we could conceive of a given child at two years of age who then proceeded to live for one year without the slightest contact with the environment, the alteration in his mentality that would have taken place by the end of that year would be the effect of the factor maturity operating alone.

By *training* I shall mean the sum total of the effects upon the intellectual operations of the individual of any and all sorts of external or environmental influences—the casual stimuli of daily life, the formal processes of education in the school, the effects of illnesses—all that we commonly think of as the effects of the environment.

With these explanations of terms before us, the immediate problem may be stated thus: Is it possible by means of our intelligence tests to arrive at a reasonably satisfactory appraisal of endowment, uncomplicated by maturity or by training? Or, in other words: Can we know the relative part played by endowment, by maturity and by training in the scores of our tests?

The Factor Maturity

Certain things can surely be agreed upon at once with respect to maturity. For instance:

(1) We never actually arrive at an indication of an endowment which is not that endowment as presented at a given maturity and as influenced by a given amount of training.

(2) There is some evidence that in the case of individual children chronological age might well be replaced by physiological age as an index of maturity. Investigators like Dr. B. T. Baldwin, who have studied this matter more fully, recommend, as I understand it, that this substitution be made. It may be that in time we shall

have criteria of physiological age that are so reliable and so easily determined that this age will become commonly accepted as the index of maturity.

(3) One obvious illustration of divergence of physiological from chronological age (and therefore of the difficulty of defining maturity) lies in the sex differences characteristic of the early adolescent period. It is known to every one that girls as a group mature physiologically earlier than do boys as a group. Studies that I am now making of thousands of scores of the National Intelligence tests show that the average scores of girls exceed the average scores of boys at the age of 11 years by almost one mental year. Incomplete data on other years appear to indicate that this sex difference is less at earlier ages but augments at about 11 and 12 years—which is, after all, what we should expect from results with other forms of mental and physical tests. As is also well known, the scores of postpubescents in the Army Alpha tests run higher for males than for females. Even if, as some contend, the content of the Army Alpha favors males, it is doubtful whether this favoring can be so great in amount as to bring the score, when properly discounted for this alleged fault of construction, to the point where females excel males so greatly as they do in the initial period of adolescence.

Consequently, concealed in these *sex* differences, we really have, as I said, a good demonstration of the operation of physiological *maturity* as a factor in intelligence scores. We are not justified, I mean, in assuming that the National Intelligence score of a 12-year-old postpubescent girl which is 10 points higher than that of a 12-year-old prepubescent boy indicates a superior endowment for the girl. The two children might well have the same endowment as well as the same chronological age.

(4) Disregarding these irrelevancies introduced into chronological age by the complication of physiological age when the two are not in step-by-step correspondence, the present methods of eliminating the factor maturity by such devices as mental age, intelligence quotients, age norms and age percentiles seem to me to have demonstrated their effectiveness by the results of repeated examinations of the same individuals; in other words, it seems to me that the constancy of the I.Q. is substantially all that could be asked for practical purposes.

(5) A problem of serious theoretical and considerable practical import appears when we seek to answer the question: At what chronological age does maturity cease to operate as a factor; in other words, what is the normal adult mental age limit? Many

pages of controversial matter have appeared on this issue. I have no intent to summarize them here. I would merely give my opinion that much of the difficulty into which psychologists have been plunged by the attempt to reconcile Binet scores and Army Alpha scores and tests of children and tests of adults lies in the fundamental difficulty of comparing directly the scores of school children and of adults on tests devised primarily for children alone or primarily for adults alone. Dr. Freeman (*Jour. of Educ. Research,* December, 1922) very properly says that we can not assume "that the average man, who has been out of school for from five to ten years, who has done very little reading and has been provided very meager intellectual stimulus, will do as well on a test standardized on school children as he would have done while he was in school." In the terminology I have been using, then, the elimination or the measuring of the influence of maturity as a factor is, in the case of those who have left school for some time, complicated by our third factor, that of training. What we need to settle this particular matter conclusively are retests after the lapse of several years with no further formal education on adults who have previously been tested while in school. I am hoping to institute an investigation of this sort shortly.

Three observations may be made at this point, however, that shed, I think, a little light on this problem of the relation of test scores to maturity.

First: In the Merrill-Palmer Nursery School operated at Detroit, where the psychological work is directed by Dr. Helen Woolley, the children, most of whom enter the school between the ages of two and five, are given a Binet test on or before entrance and are retested one or more times thereafter. A study of the I.Q.'s shows that, with a few exceptions, there is a marked rise in these I.Q.'s after six months or more attendance in the school. The question at once arises: Is the alteration here due to shifting of endowment or of training (or, perhaps, even in an acceleration of the normal rate of maturity)? Personally, I hesitate to believe that Mrs. Woolley and her colleagues have discovered a new method of heightening the I.Q. It seems to me entirely to be expected that the acquaintance with numbers, days of the month, colors and all the other materials and facts that are bound to be presented, even in the simple and informal training of a nursery school, has produced a temporary artificial augmentation of apparent mental age. Further retests, after these children have settled down in the earlier grades of the primary school, will, I venture to predict, confirm this interpretation. Here, then, is an instance in the lower age

levels of the complication by special training of the normal effect of maturity upon intelligence scores.[2]

A second observation: In comparing the scores made by college students and senior high school students in educational tests and psychological tests, I have been struck with the divergence between these two types of scores. Thus, at the University of Michigan, scores made by juniors and seniors in the Iowa High School Content Examination (which deals exclusively with factual information in literature, rhetoric, mathematics, the sciences, history and civics) show a marked advance over the scores obtained by high school seniors or university freshmen in the same test. On the other hand, the scores made by the same juniors and seniors in the Brown University psychological examination differ only slightly from the scores of university freshmen in that test. From this I draw the inference that the Brown examination is comparatively successful in measuring endowment, uncomplicated by training, and further that the pure maturity effect of the nearly four years between approximately the ages of 17 and 21 is relatively slight (this partly because some portion of the slight improvement found between the freshman and the senior year must be discounted as due to college training and also to the operation of elimination).

A third observation: I made a special attempt recently to secure satisfactory data on the National Intelligence tests for the ages beyond the elementary-school period. In one Michigan city it was possible to test every 14-year-old and every 15-year-old child. The average scores for 14 and 15 years were 139 and 142, respectively, *i.e.*, the performances in these two ages were practically indistinguishable. The annual increments of scores for the same test, beginning at the step from 8 to 9 years, are 15, 15, 17, 16, 15, 9, 3. This seems to confirm very definitely the idea that on the average at about 14½ years maturity ceases to be a factor at least so far as these tests are concerned.

[2] Another explanation is conceivable. Possibly, under some circumstances (as, for instance, when systematic training is given in the plastic early years of childhood) special training may for a time accelerate the normal rate of maturity. That is, maturity, as we have defined it, brings about a progressive ripening of intellectual efficiency, regardless of training, but this ripening might conceivably be hastened by certain types of training given at certain times. This hastening of maturity would be an indirect effect added to the direct augmentation of efficiency produced by the training. For example, the presentation to a three-year-old child of numerous stimuli, skilfully assembled in the form of educative plays and games, might stimulate in him certain activities of associating, comparing and deliberating that would not have emerged in the natural course of his internal development until a year or so later.

THE FACTOR TRAINING

In discussing the factor maturity we have already found occasion for mentioning the participation of the factor training. A few words more about this factor.

The disentangling of *training* from endowment is in some respects more difficult than the disentangling of maturity. Our usual procedure in interpreting intelligence tests is, of course, to assume that, other conditions being the same (especially extent of opportunity or amount of exposure to schooling) differences in the test scores of persons of the same maturity are fairly direct indications of differences of endowment. As I said before, we judge what the individual can do by what he does do. I believe that most investigators will agree to this interpretation, though they may not agree as to the exact precision with which performance is thus indicative of endowment.

The real divergence of opinion doubtless lies in the question: How often may we regard these "other conditions" as "being the same"? In such cases as the children in the nursery school who had two or three years of more or less systematic arrangement of their environment during what is ordinarily the pre-school age, it is perfectly evident that other conditions are not the same, that we can not then argue safely from intelligence score to native capacity.

In many other cases in which the actual educational environment has been diverse, we are, I believe, often at a loss to determine how much to discount for the superior environment, for the particular reason that endowment is itself a factor that conditions environment. It has been fairly well demonstrated, I mean, that heredity to some extent makes its own environment. Karl Pearson, for example, from his studies of heredity, is very emphatic in his assertion that differences of stock condition differences of environment. Families of superior intellectual endowment are never content with an inferior intellectual environment. The fact that such families struggle for, and usually gain, an intellectual environment satisfying their felt needs certainly influences their children through the factor of earlier, more extensive and qualitatively better training. Some considerable part, therefore, of the better scores made by these children which are *immediately* attributable to their superior training must, after all, be *ultimately* ascribed to their better endowment.

To take a concrete illustration of these complexities: a certain boy, now 9 years old and just completing the fourth grade, has an I.Q. in the neighborhood of 140. He is at least one grade pedagogically accelerated when his school grade is compared with his age. On looking over his school history, however, we find that he

did not enter school until over 7 years of age, so that, when allowance is made for this late entrance, he really is two years or more pedagogically accelerated. From this point of view his opportunities for training have been less than those of a standard child, so that his school performance is all the more remarkable. Going back a little, we discover that he learned to read spontaneously at about the age of three and one half years. At this time he began of his own accord to pick out simple words on the typewriter. When he entered school at 7, he chanced to try the Buckingham-Ayres spelling scale and scored "eighth grade" in spelling ability. Now, how is this performance to be interpreted? Strictly speaking, for a boy with substantially no public school training to attain an eighth-grade performance means, when proper allowance is made for the lack of maturity and training, that his intrinsic ability in spelling ought to be regarded as nearer, let us say, that of the twelfth grade. In other words, the attainment of an eighth-grade score while in the second grade means really better than eighth-grade ability. But, it will be objected, this boy had been playing with a typewriter for several years, hence his early training and unusual home influences have really accounted for his performance. My answer to this objection is that the fact that the boy had these opportunities set before him is one of the products of the superior intellectual endowment of his parents (presumptively transmitted to the boy), and the further fact that he profited by the opportunities set before him is one of the products of his own superior intellectual endowment, so that, on both counts, the attainment, despite the fact that it sprang from unusual environmental opportunities, merely reflects and measures superior endowment.

Further examples of this reciprocal interaction of endowment and training lie at hand in various quarters. Thus, the fact that college students, in overwhelming numbers (about 90 per cent.) score "A" or "B" grades (very superior or superior) in the Army Alpha test is, in my judgment, a demonstration of the selective influence of the college and not a demonstration of the training effect of higher education. Mention need be made only of the serious difficulty encountered by "C plus" and "C" grade students in their attempts to assimilate a college training.

The same conclusion—that intelligence tests, other things being approximately equal, are conditioned mainly by hereditary endowment—can be illustrated by reference to the correlations obtained between test scores and school performance. I am indebted to Dean S. A. Courtis, of the Detroit Teachers College, for the following illustration. When the scores in a composite intelligence test (National Intelligence test and Detroit Army Alpha) are compared with the school marks (composite of reading, writing, arithmetic,

spelling and English) the correlation for a group of a given school grade of all ages, both sexes, and mixed previous training is about 0.40. If the group is rearranged to cancel the factor maturity (by taking only 11-year-old pupils, though of different grades) and to cancel the factor sex (by taking only boys), the correlation rises to 0.60. When the group is further rearranged also to cancel approximately the difference in the value of the school marks from grade to grade, the correlation rises to 0.70. In short, endowment is seen to be the most important single factor, and it is not unreasonable to suppose that if other factors, like emotional reaction, zeal, effort, motor ability, and the like, could be held constant, and if the reliability of the school marks could be brought to perfection, the correlation between score and the factor endowment would also approximate perfection.

It might be added that a particular reason why endowment is, in practice, the most important factor to determine is that it is the one factor that we can not *control* in our educative process. Maturity we can not directly control, either, but we invariably take account of it in our educational plans. Training we must seek to control to the best of our ability, given the endowment and picking the appropriate stage of maturity so far as is feasible.

Endowment, Maturity and Training Tests

If this approximation toward a perfect correlation between intelligence score and the outside criterion of intelligence were found to be only partial, we might do well to examine our tests themselves in order to discover whether we had failed to construct them properly. I mean that we may firmly believe that theoretically endowment is a primary element in intellectual success but yet admit that our present tests may not, after all, measure this endowment adequately. Such a situation would exist, for instance, if in the composite of tasks which makes up our present intelligence examinations there are to be found certain tasks, certain individual tests, which are really little affected by endowment, though possibly considerably affected by maturity or by training.

In the second edition of his *Vorlesungen* Meumann published a proposed new system of tests wherein ten tests were assigned to each age-level and wherein these ten tests were so classified that they served as endowment, maturity and training tests, respectively. The actual plan proposed by Meumann was not practicable, nor did he give us any satisfactory reasons for assigning the various tests to the three classifications, yet the proposal raises the interesting question as to whether or not such a three-fold division is theoretically possible or desirable.

In the first place, it is questionable whether tests that are out-and-out training tests should have any place in an intelligence examination at all. It is quite true that certain tests that are obviously measures of degree of competence in certain school subjects have found a prominent place in intelligence tests; nearly all intelligence tests, for instance, designed for application in the school grades above the third have included arithmetical computation or arithmetical problems. Nevertheless, the intent has not been to measure knowledge of arithmetic or skill in the fundamental processes as such (for these purposes we employ specific arithmetical tests), but to measure intrinsic capacity, and these "schoolish" tests can be defended only on the ground that, with pupils who have all been exposed to more or less similar training in these fields, the performance shown is substantially conditioned by endowment. Quite the same thing can be said of the "range of information" tests which are also a common feature in our present intelligence tests. Personally, I believe that the effort should be made to avoid so far as possible tasks that are so directly influenced by home environment and school instruction.

In the second place, the question arises: Is it possible, or desirable to differentiate between tests of the two other main conditions of intellectual performance, between endowment tests and maturity tests? Presumably, if an analysis of scores showed that certain tests varied sharply with chronological age, but varied relatively little within a given age for children of known differences in endowment, such tests could be termed "maturity tests." (Meumann states that the immediate memory test is an instance in point.) Similarly, if the analysis of scores showed that other tests varied decidedly for children of known differences in endowment, but varied relatively little with chronological age, these tests could be termed "endowment tests." On the basis of tests conducted with feeble-minded children of a limited range of ages, Chotzen ("Die intelligenz-Prüfung Methode von Binet-Simon bei schwachsinnigen Kindern." *Zeits. f. Angew. Psych.* 6: 1912, 411–494) declares that this differentiation appears clearly; the maturity tests, or "age-tests," as he calls them, are those concerned with frequently performed activities and the experiences of everyday life, whereas the endowment tests are those that present something new, demand something novel and necessitate keenly concentrated attention. Claparède ("Tests de développement et tests d'aptitudes." *Arch. de Psych.*, 14: 1914, 101–107), who has also been interested in this problem, has proposed what seems like a severe measure, that tests shall be deemed maturity tests only when the difference between the average performance of two successive age-levels shall be at least four times the probable error of the distribution of the scores

of a single age-level, or only when the percentage of right answers (in the case of "all-or-none" tests) increases from 10 to 80 from one age-level to the next.

When to these difficulties of a statistical sort are added the further complications that some tests appear to correlate more definitely with maturity in one respect but with endowment in another respect, and that the great majority of tests after all correlate definitely with both maturity and endowment, we are led to question whether the differentiation between these two types of tests is really feasible in practice. Further comparative studies might, I judge, be carried on to good purpose in this direction. Generally speaking, it would seem desirable to exclude from our intelligence examination any test that exhibited marked correlation with chronological age coupled with low correlation with endowment.

As to the great majority of tests, which, as just mentioned, exhibit definite correlation with both maturity and endowment, are we not warranted in saying that it is precisely this type of test that we seek if we are to work on the basis of mental ages at all? Was it not the essential feature of Binet's plan that the quantity of endowment possessed by a child should be determined by comparison with the degree of endowment normal to children at a given stage of maturity? Naturally, we are committed by this analysis to the further assumption that endowments which differ at the start will exhibit similar (or perhaps even greater) differences at various subsequent stages of maturity; in other words, we are committed to the doctrine of the substantial constancy of the I.Q. Certainly we can not hope at present to devise any satisfactory series of tests that shall measure endowment regardless of the effects of maturity. We work on the basis that performance superior to the average performance for the stage of maturity reached means superior original endowment.

It had been my original plan to conclude this paper with a statement of the general arguments for the fundamental significance of hereditary endowment in intellectual performance and a discussion of the very important problem of the extent to which training at different stages of maturity is conditioned by different degrees of endowment. I would have liked, for instance, to debate Bagley's hypothesis that while "vertical growth," as he calls it, is limited, the possibilities of "horizontal growth" are essentially limitless. In a way, these are problems of general educational psychology and only subsidiary issues of the theory of intelligence testing. You will be glad to pardon their omission at this time and for reasons of time economy to pardon also the absence of any summary of this paper.

THE INTERPRETATION OF INTELLIGENCE TESTS[1]

By J. McKEEN CATTELL

We are conscripted to talk this morning about the interpretation of our intelligence tests, with special reference to the problem of the extent to which the performance of the individual depends on his heredity and on his environment. The scientific method of interpreting psychological tests is to continue research with them. Definitions and discussions are relatively futile for the advancement of science; but they may serve a social function. Certainly if we want to play a complicated game of logic and logomachy, heredity, environment and intelligence are excellent counters.

Apart from theology there is perhaps no subject so inaccessible to scientific research, so open to endless discussion, as is human heredity.

> As flies to wanton boys, are we to the gods,—
> They kill us for their sport.

Professor Morgan and his thirteen disciples can mate, etherize and count their flies by the tens of thousands. It requires the omnipotence of the gods and the time of their slowly grinding mills to make in men modifications equally significant; and they breed and kill us for purposes other than the collection of scientific records. Only in the fable can Fata Morgana transform a human being. Morganatic marriages for experimental results are not favored by existing law and sentiment.

When I became editor of *The American Naturalist*, it was with the intention of making it a journal devoted to research on heredity and organic evolution; my own interest was in human heredity and eugenics. Within these twenty years a science of genetics has been created, but there have been submitted to the journal scarcely any papers of consequence on human heredity; not many have been published anywhere. When the International Congress of Eugenics met in New York two years ago, there were many officers and members, but scarcely half a dozen of them professionally engaged in eugenical research.

Some three hundred years before there was a Davenport in Iowa or in Cold Spring Harbor, Hakluyt in his "Voyages" wrote:

[1] Part of the Symposium of the Section of Psychology of the American Association for the Advancement of Science at the Cincinnati meeting, December 31, 1923.

"I reason that as some sicknesses are hereditarious and come from father to the sonne, so this inclination or desire of this discovery I inherited of my father." This is the natural extension of the concept from its original application to the inheritance of rank and property and is the current usage; thus the "Century Dictionary": "The influence of parent upon offspring; transmission of qualities or characteristics, mental or physical, from parents to offspring;" and the "Oxford Dictionary": "The property of organic beings, in virtue of which offspring inherit the nature and characteristics of parents and ancestors generally."

We might expect better things in Baldwin's "Dictionary of Philosophy and Psychology" where the definitions are signed by experts, but we find heredity defined conventionally as "The transmission from parent to offspring of certain distinguishing characteristics of structure or function." This definition is scarcely an example of the transmission of characteristics from parents to offspring, for, according to the signatures, the mountains which were in labor to bring forth the little monster were Professor J. Mark Baldwin, Professor E. B. Poulton, Professor William James, Principal C. Lloyd Morgan and Professor G. F. Stout. It is inept to personify heredity, to make a fundamental distinction between structure and function, to speak of characteristics as things apart from the organism handed down like property, or to make the parent (why not at least the parents?) solely responsible. In general, however, the usage is the current one, and if we define heredity as "The resemblances among individuals due to their common origin or germ plasm," we have the problem to which our genetic investigations are directed.

But in the subject proposed for this discussion, "Heredity *vs.* environment in the interpretation of our intelligence tests," heredity has a different meaning, namely, the congenital equipment or the original organization of the individual. This usage has biological sanction; for example, Professor J. Arthur Thomson in his book on "Heredity" writes: "Heredity, function, and environment —famille, *travail,* lieu—are the three sides of the biological prism, by which, scientifically, we seek to analyze the light of life." This is a curious sentence, as light is analyzed by two, not by three, sides of a prism, and experience is not coordinate with congenital equipment and environment, but dependent on them. Galton, whose intellectual vision was always sharp, uses what he calls the "jingle" of "nature and nurture," to mark the distinctions with which we are here concerned. He says: "Nature, or the sum of inborn qualities . . . includes also those individual variations that are due to causes other than heredity, and which act before birth." And

Brooks: "We must recognize the universality of the law of heredity, but we must not overlook the equally well-established fact that each organism is the resultant of this law and another, the law of variation."

As we have no satisfactory word for the constitution of the fertilized ovum—the zygote—it is a temptation to use heredity, but it causes confusion. Thus, on the one hand, the zygotes of two brothers might by hypothesis be assumed to be identical, but the influence of environment to be so dominant that under different conditions there would be no resemblance between the two adults. Or, on the other hand, the zygotes of the same parents might conceivably vary normally about the racial mean, but two similar zygotes, whatever their origin, might under diverse environments produce similar adults. With which of these extreme hypotheses would heredity be strong or weak? We apparently should find or invent words to designate the individual when it is a zygote and when it is born, and the extent to which at these stages the growing or adult organism is determined.

Environment is also a complicated concept. It is a term that I have never liked; for some obscure reason it reminds me of "that blessed word Mesopotamia." Alcohol is no longer part of our lawful environment, but it may on occasion be found in the brain. Is it then part of the organism or of the environment? To which do vitamins, hormones and internal secretions belong? The behavior of a blind man is dependent on this condition. Blindness may be due to organic heredity or to chemical changes induced in the germ plasm of the parents; it may be caused by infection in the uterus or by subsequent disease to which there is congenital disposition; it may result from actions due to imbecility or from driving a car recklessly; it may be due to lightning from heaven. We lack everywhere sharp lines between the organism and the environment. The reactions of an individual are determined by stimuli acting on a nervous system formed largely by preceding experiences, and in an environment which is largely a social heritage.

Even if we know exactly what we mean by our words, it is not possible to answer categorically the question whether the intelligence displayed in our tests is due to heredity, or to environment, or to a certain proportion of each. Mr. Lippmann would not care to answer the question: Did you misrepresent the opinions of psychologists in your *New Republic* articles through ignorance or through malice? To ask whether the performance of an individual is due to "heredity" or to "environment" is like asking whether the color of a flower is due to the molecular structure of the petals, to the light that they diffuse, or to the perceiving individual. To

use the old simile of Aristotle: "A hand apart from the body is no longer a hand." The organism and the rest of the world with which it comes in contact are one and inseparable. When the blind lead the blind and both fall into a pit, it is not easy to say whether the result is due to the individual or to the environment. And so it is with the actions of Kaiser Wilhelm or Czar Nicholas. A boy may do about as well in his college work by natural ability tempered by athletics and fraternities, or by lesser ability more continuously applied. The same causes produce the same effects, but the same effects can be produced by varying causes. "Some men are born great, some achieve greatness and some have greatness thrust upon them."

Darwin and Lincoln were born on the same day. Darwin came from a highly endowed family with all the advantages of wealth and privilege. He chanced to go on the voyage of the *Beagle* and lived when and where evolution by natural selection—witness Wallace—was in the air. Lincoln had no hereditary advantage or favorable surroundings; but he too had high natural ability and finally the opportunity of circumstance. If the two infants had been exchanged there would have been no Darwin and no Lincoln. Was the performance of each due to natural endowment or to opportunity, or to any quantitatively determinable proportion of the two? Is the amount of the extension of a spiral spring due to the structure of the spring or to the weight attached? As nearly as the matter can be put in a sentence we may say that what a man can do is determined by his native equipment, what he does do by the circumstances of his life. We can not gather figs of thistles; neither figs nor thistles will grow where there is no water.

If there are difficulties in reaching a common understanding in discussing heredity, environment and their interrelations, the situation is not other with regard to intelligence. The psychologist is likely to consider intelligence as the quality enabling an individual to learn readily or to meet new situations successfully, in so far as this depends on his congenital equipment. This is what we mean when we say that a dog is more intelligent than a horse, or to quote Hakluyt again: "In my judgment there is not a beast so intellective as are these eliphants, nor of more understanding in al the world; for he wil do al things that his keper saith, so that he lacketh nothing but humaine speech."

In common usage, however, intelligence means information, especially the limited sort possessed by intellectuals or the intelligentsia. Thus the *Dial* heads its December advertisements: "It is now the fashion to be intelligent," and continues: "Until recent years it was still considered fairly bad form to be intelligent; to be

well-read was either a snobbish superfluity or a social misdemeanor.'' Intelligence is not only used for information and appreciation in literature, but we are told of intelligence departments of the army, where spies and clerks collect dubious information, and in America we call places ''intelligence offices'' on the Ciceronian principle of *lucus ab non lucendo.*

Our intelligence tests may not be misnamed, for they measure the combined natural and acquired ability of the individual to deal promptly and correctly with relations that are largely verbal and mathematical. This kind of intelligence is needed for success in school and college work, so here the tests have a considerable predictive value. Such abilities develop with age; the child reaches a stage at which he can talk, read, calculate or acquire certain kinds of information, as happens with walking, swimming or playing tennis. Genetic tests of the Binet type thus have great value in determining mental age, but this is a concept that should be applied with caution to adults. It is also the case that the qualities measured by the tests are required in our present civilization, especially in the professions. But the ambiguity of the word intelligence may lead to false interpretations. It may mean a hypothetical native quality that leads to success in most situations, or it may mean acquired skill in dealing with words and numbers. We may measure the latter and assume that we have determined the former.

It seems that I was responsible for the first psychological measurements of ''individual differences'' and for the invention of this term as well as of the term ''mental tests.'' My experiments on the rate of reading and its dependence on the method of presentation, published in 1885, were of the intelligence test type. It may, perhaps, be now revealed without indiscretion that John Dewey, then my fellow student, stood highest in the group tested. I found that a word could be read as easily as a single letter; that a subject might require about one half second to read a single word, about one fourth second each to read disconnected words in series and about one eighth second each to read words in sentences. In reading different languages aloud as rapidly as possible without attention to the meaning, my own time per word in thousandths of a second was: English 138, French 167, German 250, Italian 325, Latin 434 and Greek 484. The relations were found to measure the individual's ability in the language. It took about twice as long to name a color or an object as the word designating it for those habitually engaged in reading, but not for others. The times of the different observers were distributed approximately in accord with the normal probability curve, within a range of about 1:2, which I have found to hold for many psychological measurements of indi-

vidual differences, such as reaction-time, observation, memory, association and judgment.

In 1887 and 1889 there were described in the *Philosophische Studien* and in *Mind* over 12,000 experiments on the association of ideas on the lines of our present intelligence tests. The subjects included the students of a German gymnasium, a London school, a Dublin school and Bryn Mawr College. The experiments were published some ten years earlier than the work of Dr. J. M. Rice, which is often quoted as the first quantitative study of school children, and some twenty years before the Binet tests, which are usually regarded as the first genetic or age intelligence tests. In four forms of the London girls' school the average ages of the students were 12.7, 14.8, 16.3 and 17.8 years; the average times of their associations in seconds were 9.33, 6.09, 5.16 and 4.13. There was also a regular increase with age in the percentage of abstract associations.

The following paragraph scarcely seems antiquated:

> The 363 students of the London school were divided, according to their class-rank, into four parts. The average time of association for each quarter is given in Table IV. This shows an increased rate of association as the class-rank of the students is higher, but the difference is not great. Indeed, it is possible that such experiments measure the alertness of the student's mind more accurately than does the class-rank, which depends largely on diligence and other factors not telling in such experiments. The table does not show a difference for the several quarters in the relative rate of the concrete and abstract associations; consequently higher class-rank does not seem to be accompanied with greater ease in abstract thought, attention to objective details being equally useful. (*Mind*, XIV, p. 235, 1889.)

I then employed the word alertness and still prefer it to intelligence. Scott uses the term "mental alertness tests," but the adjective is unnecessary. The designation "psychological tests" seems to be preferable to "mental tests" or "intelligence tests." Ability is a better word than intelligence, for we can speak of different kinds of abilities, and the word refers to measurable performance rather than to mysterious mental powers. I have always held that psychology has to do with the conduct of an individual rather than with his consciousness. We are concerned with what a person does, rather than with what he thinks he thinks, feels he feels or imagines he imagines. In psychological experiments, as I once put it, "It is usually no more necessary for the subject to be a psychologist than it is for the vivisected frog to be a physiologist."

Perhaps some light is thrown on the contemporary interpretation of intelligence tests by the following, written nearly forty years ago:

> The differences of time in the several cases are explained by the character and pursuits of the subjects, and in turn throw light back upon these. For

example, B is a teacher of mathematics, C has busied himself more with literature; C knows quite as well as B that $5 + 7 = 12$, yet he needs 1/10 seconds longer to call it to mind; B knows quite as well as C that Dante was a poet, but needs 1/10 seconds longer to think of it. . . . In giving the language in which an author wrote, as average of the three trials, . . . in the case of Luther B took 244, in the case of Goethe 102σ less time than C; in the case of Shakespeare C took 186σ less time than B. It should be borne in mind that B is a German, C an American. . . . Such experiments lay bare the mental life in a way that is stratling and not always gratifying. (*Mind*, XII, p. 71, 1887.)

In the "Physical and Mental Measurements of the Students of Columbia University,"—which in accord with the present system of psychological nomenclature and to make permanent an otherwise untenable association might be called the "Cattell-Columbia tests" —published in 1896, the effort was made to measure or record a large number of specific individual traits. In the course of an hour some twenty-six measurements were made in the laboratory and some forty-four observations were recorded. Later the student sent in answers to some fifty questions in regard to his origin, condition, habits and interests. We had his records in class work and in the gymnasium; information concerning non-scholastic college activities was available. What the men have done in the subsequent twenty-five years and the measurements of the children of some of them at present in college could now be correlated with the original determinations. The measurements were made on women at Barnard as well as on men at Columbia—about a thousand in all—and were genetic tests; for the same individuals were tested at the beginning of the Freshman and the end of the Senior year.

It is to be hoped that these references to early work are not symptoms of arteriosclerosis. It seems to me that in recent years exact measurements of psychological traits and reactions have been relatively neglected for the more general and complicated intelligence and information tests, whose immediate usefulness is greater. Perhaps the best way to interpret intelligence tests is to study the more elementary forms of behavior on which they in part depend. Individuals were found in these Columbia tests to differ in strength, fatigability, vision, hearing, touch, accuracy and rate of movement and of perception, observation, attention, imagery, memory, association, etc., but there was little or no correlation among the measurements or of these with the class standing of the student in different subjects. This lack of correlation may, however, be in itself of interest. It parallels the lack of transfer of training found by Professors Thorndike and Woodworth in the Columbia laboratory.

It may be that quickness and accuracy are not directly correlated. They may be inversely correlated; but both are useful traits. If there is no correlation, 25 per cent. of individuals would be above

the median in both quickness and accuracy and would have a distinct advantage. If "intelligence" and "character" are not correlated, one per cent. of all individuals would stand in the upper tenth in both characteristics and these would tend to be those who are successful in their behavior. Psychologists do not hold that there is a comprehensive and unanalyzable native general intelligence on which the success in life of the individual depends; but such opinions are attributed to them, and it may be that individual psychologists have not always expressed their meaning with sufficient care and caution.

In my study of eminent men, begun in the eighties, I applied psychological classifications to group them as men of thought, men of action and men of feeling. I have noted the analogy of thought, action and feeling to the wider categories of space or extensity, time or protensity, and energy or intensity, and also the circumstance that performances are not divided among the three kinds of activities, but possess them in varying degrees, as a body may be round, moving and hot at the same time. These distinctions were used in grading character and in arranging individuals in the order of merit for different traits. Some people are most happy and successful in abstractions, all the way from solving newspaper puzzles to framing systems of philosophy, others in social relations or artistic activities, others in doing practical and objective things. These abilities are combined in varying degrees and relations and are then exhibited in different kinds of performances. Human nature is endlessly complicated and the kind of analysis that can be made with pen and ink is rather futile. We are told that thought is antithetical to feeling and action, but accomplishment in some directions rests on a combination of the three, witness, for example, British premiers such as Gladstone and Lloyd George. Even so we have not settled with the question of clearness of thought, sincerity of feeling, correctness of action. Wisdom, sympathy, righteousness are still further beyond our present reach.

In all this complex the intelligence tests only attempt to determine a small range, primarily of the intellectual processes. If children have had much the same home and school life the tests measure native differences in what an individual can and can not do. The morons at the bottom will not be found in the upper school grades, but may be conscripted to serve in an army. A girl in the lower deciles may be a good housemaid but a poor typist; somewhat higher, she may be a competent typist, but a stupid stenographer. Freeman says in his excellent study in the December *Century Magazine*, that "leadership in the professions, in business and in larger political life" is confined to the upper five or ten per

cent. I should prefer to guess that nine tenths of the leaders would be placed by our tests in this group. Among the five or ten million Americans thus designated the correlations are uncertain and vary with the kind of performance. To be a Phi Beta Kappa man or an Alpha A + man is an introduction to "Who's Who" and a salary of $5,000. The men who build cities, railways and industries are not selected by intelligence tests.

When it is found that Italian children in our schools do not do so well in certain tests as native American children, this may be due simply to lack of familiarity with the language or to ease in understanding the instructions. The children in the Montessori schools seem to be particularly precocious in tests of the Binet type. In any case the Italians may have forms of expression unattainable by the usual Anglo-Saxon. When Irish children do not do as well as some others, it may be due only to different interests in the home, but these interests may reflect real racial differences. The tests may predict that the Irish children will not do as well as American children in bookkeeping and stenography; but they do not directly measure the probable success of the two groups in keeping saloons, running Tammany Hall, writing poetic drama, or starting rows. There is in fact fair agreement among psychologists on the scope and meaning of intelligence tests. The difficulties are largely in the minds of journalists and educators, as Professor Whipple pointed out in the admirable review of the subject in his address given a year ago as chairman of the section of education of this association.

The proper interpretation of intelligence tests consists in learning what an individual will do in a given situation, what are the conditions leading him to act as he does, how well we can predict this. Our current tests foretell as accurately as an entrance examination or a high-school record what a boy will do in college. That is practically important for it gives a more nearly equal chance to those who have had varying opportunities. Boys from the private preparatory schools pass the college entrance examinations more readily than those from the public high schools, but they do not do so well in their studies afterwards. What is hopeful about the tests is that they predict what a boy can do even more accurately than what he will do. In this direction future research is full of promise. No work seems to me more important for society than Terman's on the selection of talented children. A great forward step has been taken when psychology is applied to useful purposes and the way is made straight for a profession that may become as serviceable as medicine or engineering.

THE ORIGIN, NATURE AND INFLUENCE OF RELATIVITY[1]

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III. The Old and New Theories of Gravitation

It is a commonplace of experience that when material objects are left free, they fall to the earth. If suspended from above they stretch downward, and if supported from below they flatten in the same direction. It is customary to think of such effects as due to gravitational force. This force acts with nearly the same intensity everywhere on the earth's surface. Very careful experiments indicate that it is proportional to the mass or quantity of matter concerned.

It may have been felt in early times that some force of analogous nature keeps the heavenly bodies in their prescribed paths. Kepler had specific ideas about gravitation, nearly all of which were correct. He conjectured that the *virtus motrix* diminished as the distance between the bodies increased, in particular inversely as the distance. However, the mathematical tools necessary to deal with the questions at issue had not then been invented; these were the analytic geometry of Descartes and the infinitesimal calculus of Newton and Leibniz.

The possibility that the force varied inversely as the square of the distance, so that when the distance was doubled the force diminished to one quarter of its magnitude, interested Newton as well as several of his contemporaries. It was the extraordinary accomplishment of Newton to have established with the aid of the calculus that this law of force holds with a high degree of accuracy throughout nature, by applying it to the solar system, comets, tides, etc. The subsequent more thoroughgoing application to nature has required notable mathematical skill as well as extensive computation, and the agreement of theory and the observed facts has been ascertained to be nearly complete.

The Newtonian law is unparalleled in the realm of physics because it calls for the instantaneous spreading of a disturbance throughout all space. Thus, if a material object is moved suddenly, the disturbance in gravitational force caused thereby is supposed to affect instantly the most distant stars. No explanation of the law has been forthcoming which accounts for it as a secondary

[1] Lowell lectures.

result of the properties of matter and electricity. Substantially all that has been done is to state the law and deduce mathematically its many consequences.

It would be unreasonable to expect a complete explanation of a phenomenon as basic as gravitation, and yet there is much to be said that is well worthy of careful consideration. A complete explanation of any set of facts undertakes to account for them in terms of still more fundamental accepted facts. For instance, heat may be explained in this way as molecular motion, discerned in a gross statistical way by means of the senses. To whatever extent this kind of explanation may be carried, there must remain other facts, taken for granted and not explicable in the same satisfying manner. There is, however, another imperfect kind of explanation (such as is here attempted for gravitation) which may be possible. For instance, geometry can be developed from a few intuitively accepted truths into all its infinite and beautiful variety by means of systematic reasoning. Such a development gives an excellent example of the second type of explanation. Another illustration of the same type is found in the so-called analytic theory of heat, where a few reasonable assumptions, such as that heat is a measurable quantity and flows from hot to cold, yield a complete theory by logical development.

It will appear that the law of gravitation is similarly predetermined by its broad qualitative properties as an interaction between bodies not in direct contact, together with the principle of relativity present in the particular framework of the physical universe which is taken as starting point. This is true of the theories of gravitation of both Newton and Einstein. Consequently it would seem that the law of gravitation expresses in the simplest possible terms the direct purpose of nature that material bodies tend to approach one another in empty space.

In the framework of space and absolute time at the base of Newton's theories, any undisturbed body yields an attached reference space in which other undisturbed bodies move with uniform velocities in a straight line. Let us select some such space of reference. Any other space which moves relatively to the selected space with uniform rectilinear motion will serve equally well.

The type of relativity which is present in the special model forming the starting point is particularly to be noted. Here the bodies are so small and so far apart that they may be treated as point particles which do not disturb one another. The special model may be considered to be realized with high exactitude in interstellar space. Now what is the type of relativity referred to? It is that a particular space can be replaced by any other space

moving uniformly in any direction, and also that particular units of length and time can be replaced by any other units, without change in the statement of physical laws. It is natural to try to maintain such a relativity in the generalization of the special model to space and time taken as the container of interacting matter. In another form, this requirement means that the physical properties of bodies are to be thought of as independent of velocity and orientation in the selected space.

First let us consider briefly the contact forces such as arise when equal, rigid, spherical particles happen to collide. The two particles will move with constant velocities along straight lines before collision. The point P midway between their centers will do

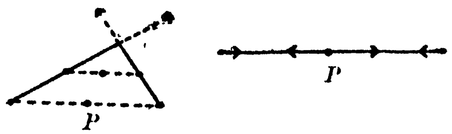

Fig. 1

likewise. Let the space of reference be taken to be attached to this point, P. Then in the equally valid new reference space, the two particles will approach one another with equal velocities in opposite directions and collide at P. It is assumed for the sake of simplicity that the collision is direct and not glancing. The recoil must be in the straight line joining the two particles, if the principle of relativity which obtains in the special model is not to be destroyed. In fact, otherwise, the result would not be independent of orientation in the space selected. Likewise, the two velocities of recoil must be equal, or there would be a physical distinction between the two directions on the line of approach. Finally, if we interpret the relativity of time in the mathematical sense that the unit of time can be changed to its negative, (*i. e.*, that any series of happenings can be described in the reverse order), it appears readily enough that the velocity of recoil must be the same as that of approach.

Thus the entire behavior under direct collision is determined, and, by reference back to the original space, it is found that the laws of collision are such as to leave unaltered the momentum and energy as well as the mass of the pair of colliding particles. By such means, with the natural and inevitable extension to gases, liquids and solids, as obtained by aggregation of molecular particles, the behavior of bodies in contact can be determined in large measure by the mere requirement that the relativity of space and time remains as extensive as in the special model.

The alternative kind of force is that which acts between bodies through empty space. Let us see how it is that such gravitational

force is determined in character by the same requirement that the relativity present in the special model be preserved.

It should be observed that the word *force* as used here and earlier has no metaphysical significance. When any particle departs from motion with constant velocity in a straight line, then, in the momentarily attached Newtonian space, the particle will be leaving its position by a definite distance in one second. Such a displacement in position for each unit of mass is the measure of the force which acts. Hence we can define force by purely geometrical methods based on a measurement of displacement from uniform motion in a straight line, and this is the definition adopted here.

Now the Newtonian analysis of space and time is incomplete to the extent that it proceeds as if light were propagated instantaneously. But such a restriction only means that the velocities of bodies are of very small magnitude in comparison with the velocity of light. In order that such a situation be maintained, it is necessary that only bodies of small mass be considered. It is, therefore, a restriction to the case of small masses and velocities.

Take first two equal spheres of small mass relatively at rest, held at a fixed distance apart by a very light rigid bar. If the bar is removed, the mutual influence hypothesized must necessarily result in a displacement of the spheres along their line of centers, measurable as a force. This conclusion follows by the principle of relativity used before. The magnitude of the force can only depend on the distance between the spheres. Unless some particular absolute unit of length exists, the force must vary as a power of the distance, as a little mathematical argument would show; the existence of such a unit of length is inconsistent with the same principle of relativity. The force can not vary directly as a power if it is to vanish when the two bodies are at a great distance from one another. It can not vary inversely as the first power of the distance, for in that case bodies approaching one another from a distance acquire indefinitely large velocities by mutual influence. Nor can it vary inversely as the third power or a higher power, for then the mere aggregation of continuous matter provides an infinite supply of energy. Thus, by very obvious requirements, the range of choice appears effectively narrowed down to the law of Newton, according to which the force varies inversely as the second power of the distance.

Although only the gravitational interaction of two small equal spheres has been considered, the principle of the superposition of small effects, widely observed in nature, is of service in the determination of the forces of interaction between any number of equal

or unequal small bodies. A simple illustration of this principle is afforded when sets of circular ripples, caused by as many pebbles striking the surface of the water at different points, meet. The height of the combined wave is the sum of the heights of the separate waves. The principle of superposition is one that holds by virtue of an inner mathematical necessity rather than an independent physical principle.

Hence the mechanical and gravitational laws of interaction are determined, once the Newtonian framework of space and absolute time is accepted, and the full relativity of that framework is insisted upon. The logical incompleteness in the preceding development of this fact is by no means to be ignored, but the fact itself seems undeniable.

One limitation in that theory arises from the circumstance that it takes no adequate account of the finiteness of the velocity of light. Accordingly, any inaccuracy in the law of gravitation obtained is likely to manifest itself when the relative velocities are high. In particular, it would be expected that, of all the planets, Mercury would deviate most from its predicted orbit, for it moves with the highest velocity of any planet under the solar attraction. Such a deviation has been observed.

Furthermore, when this framework is adopted, it is not possible to maintain the same degree of spatial relativity in dealing with electricity and magnetism. This is also to be anticipated, since light is electromagnetic, and the disregard of its velocity is particularly improper from the electromagnetic point of view. It thus becomes necessary to adopt the absolute space or ether of Faraday and Maxwell.

The diagrammatic circle of relativity may be used to illustrate the considerations adduced above. Consider the circle with the infinitely many symmetric reference lines through its center, representing the relativity which is present at the outset in the Newtonian framework. Suppose that a point in the plane of the circle is to be specified in such wise that the symmetry is not lost. The point must necessarily be the center. Or suppose that another circle is to be specified under a similar condition. It must have the same center as the first circle. On the other hand, if it is demanded that a line be laid down, the symmetry is necessarily destroyed. The mechanical and gravitational laws are analogous to the point and circle to be determined. The fact that these laws are in accord with the principle of relativity indicates the basic importance of that principle. On the other hand, the laws of electromagnetism are inconsistent with the principle, and so are akin to the straight line.

If the above analysis is correct, the heuristic value of the prin-

ciple of relativity for classical physics can scarcely be overestimated. With it the form of the laws of mechanics and gravitation seem predetermined, while without it these appear to be given at random. The laws of electricity and magnetism are not so predetermined, however, in that theory.

In passing to the special theory of relativity invented by Einstein in 1905, we begin with a more adequate analysis of space, time and light, and obtain a corresponding framework. Any undisturbed particle defines a particular space and time relative to itself, in which interacting matter is taken to be present. When it is required that the new, spatio-temporal type of relativity of the special model be strictly preserved, a very interesting situation results. The laws of contact action of elastic bodies can be determined by means like those available in the Newtonian case. Slightly modified principles of conservation of mass and energy, and momentum are obtained, in such wise that the theory agrees with the known facts of mechanics at the velocities found in nature.

The account given of the electromagnetic theory in empty space becomes extraordinarily symmetric with this type of relativity. The theory may be approached very readily by means of a few broad qualitative assumptions and by use of the principle of spatio-temporal relativity. The symmetry between space and time is so complete that one is justified in writing down the correct dimensional equation

$$186{,}300 \text{ miles} = \sqrt{-1} \text{ seconds.}$$

The meaning of such a mystical equation can not be elaborated here: it indicates a formal symmetry between the properties of space and of time. This peculiar kind of symmetry is found throughout the theory.

If now we proceed to consider the interaction of bodies at a distance, it appears that, in the case of sparsely distributed matter at rest in some space, the law must be of the Newtonian type for the very reasons advanced before. The appropriate extension to the case of matter in relative motion may be obtained by the so-called principle of the permanence of mathematical form. In applying this principle, the simplest law is sought which is consistent with the principle of relativity and which reduces to that of Newton for such a static distribution of matter.

Any beginner in algebra who knows that a^1 stands for a, a^2 for a times a, a^3 for a^2 times a, etc., sees that a law of combination by addition of exponents holds, so that a^2 times a^3 equals a^5, for instance. If asked how to interpret $a^{1/2}$, he observes that by the same law of combination $a^{1/2}$ times $a^{1/2}$ ought to be a^1 or a. Hence he infers by the principle of permanence of mathematical form that $a^{1/2}$

ought to stand for the square root of a. This principle has been found of the greatest value for heuristic purposes, and can be extended remarkably.

The law of gravitation so obtained will not account for the anomalous behavior of the planet Mercury. If it were not for this deficiency it is probable that the general theory of relativity of 1915 would not have been advanced by Einstein, since the elegant special theory of 1905 possesses the same degree of generality in its principle of relativity as the theory of Newton, and yet includes electromagnetic as well as mechanical and gravitational phenomena.

The qualitative explanation of gravitation, as far as it has been attempted here, indicates that the essential element in any new approach is likely to lie in the use of a better spatio-temporal framework. Concerning any available framework a good deal may be said in advance. In particular, if it is desired to retain anything of the older theories, it will certainly be necessary to hold to the notion that the totality of physical events corresponds to a "four-dimensional space-time continuum." This statement only means that events can be specified by means of three space numbers and one time number.

It was the mathematician Minkowski who pointed out in 1908 that, in its aspect of mathematical form, the space-time continuum of the special theory of relativity is highly analogous to ordinary space; in fact it *is* ordinary space (in the same mathematical sense as that in which the mystical equation written above holds) except that an additional dimension is present. The events are the points, the collections of events at a single particle, called "world lines," are the straight lines, the local time elapsed between two events at a particle is the distance between them, and the space appertaining to a particle at any instant of its time is a three-dimensional "hyperplane" perpendicular to its world line.

Now, in a sense to be explained in a moment, ordinary space is a continuum without "curvature."

It is natural to ask in consequence: Can not the framework of space-time be made more flexible so as to correspond to a continuum with curvature? The question may be restated as follows: Can not a space-time framework be used which bears to the framework of the special theory of relativity the same general kind of relation as a curved surface does to a plane? It is clear that this involves a necessary requirement that each small part of the new space-time is like the space-time of the special theory in the same sense as a small piece of a curved surface is like a plane. There seems to be little doubt that Einstein's general theory of 1915 took its origin in some such line of thought as that just indicated.

A more physical statement of the central idea of the new theory may be formulated as follows: Consider an elevator cage dropping freely toward the earth. The effect of the gravitational force of the earth appears thereby completely done away with. For example, a ball thrown in the cage will describe a straight line relative to it, just as if the cage were in empty space remote from matter. This fact suggests strongly that the space and time of any one small reference particle in empty space are the same as of any other in physical properties, and that these properties have no explicit reference to gravitation. From such a point of view, gravitational effects arise because of the fact that every part of a body tends to follow a natural path, except as it comes into juxtaposition with other parts of the body.

The meaning of this interpretation may be made more apparent in another illustration. Consider a fly on a horizontal merry-go-round. The merry-go-round will have the same physiological effect on the fly as if stationary and inclined to the horizontal, the angle of inclination being dependent upon distance from the center, and increasing with the distance. In this way a pseudo-gravitational effect is produced by the conflict between the natural motion of the merry-go-round and the natural motion of the fly.

It is evident that the relativity of physical properties to the particular particle in empty space can not be complete. For example, in the dropping elevator cage a magnetic needle will still point toward the north. Einstein requires relativity to hold to the extent that measurements with a small clock and measuring stick can be properly made. In other words, he assumes that the familiar relations between space, time and light hold at every small particle in empty space.

The new spatio-temporal framework is by no means completely determined by the single requirement that it is comparable to a spatial continuum. Each little part of it may be like the space-time of the special theory, in the same sense that a piece of a curved surface is like a plane, and yet a great deal of arbitrary adjustment is still possible. To effect the determination of the space-time continuum, it is necessary to discuss its intrinsic properties which, like those of any surface, hinge upon the important but technical concept of "curvature."

Consider the geometry of the plane. It may be developed independently of the fact that the plane is a part of three-dimensional space. For example, a straight line might be defined as the shortest path in it. If this kind of approach is made, a conical surface can be treated in exactly the same way as a plane, for it has precisely the same internal properties as a plane. To demonstrate the fact,

it is only necessary to unroll the conical surface upon the plane. The geometry obtained indicates that the plane is similar to itself in all its parts, to the extent that, if distances are reduced by half, the plane has the same properties as before.

Now consider the geometry of the surface of the sphere in a similar spirit. The shortest line between two points is an arc of a great circle on the sphere. Furthermore, all parts of the sphere are alike just as all parts of the plane are. Angles have the same significance as in the plane.

Nevertheless, there is a characteristic difference, for the sphere is not similar to itself; for instance, if the radius of the sphere is doubled, the surface of the new sphere can not be fitted upon the old one without distortion of distances. The curvature of the sphere is measured by the extent to which the property of similarity of figures fails to hold; the plane has no curvature, and is thus flat, from this point of view.

If we consider any other arbitrary surface, like an ellipsoid, it will depart from similarity to itself at each point by an extent measured by the curvature. This curvature has nothing to do with the ellipsoid thought of as situated in three-dimensional space, but is a quantity fixed by the internal properties of the surface.

In the same way the curvature of a spatial continuum of more than two dimensions can be defined by its internal properties.

Einstein requires that space-time be as flat as possible away from matter without degenerating into the flat space-time characteristic of his special theory. This is entirely akin to the requirement that an ordinary surface not a plane contains as many straight lines as possible. The solution of this more elementary problem is indicated in the figure shown herewith. Likewise he requires space-

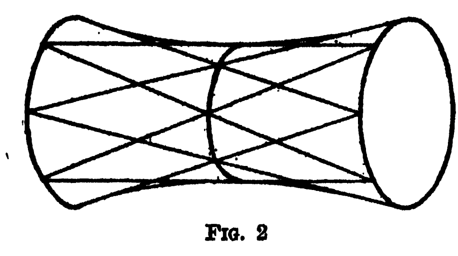

Fig. 2

time to have curvature where matter is. It turns out that space-time is satisfactorily prescribed by means of these two requirements.

Gravitational phenomena are now explicable as the inevitable result of this curvature. More concretely, the fact that two bodies in empty space tend to approach one another is comparable to the fact that any two great circles on a spherical surface will intersect one another. The new general theory obtained explains even the

anomalous gravitational behavior of the planet Mercury, and has been widely accepted on the basis of this and other experimental evidence.

It is very important to understand the essential modification which the principle of relativity undergoes in its extension to the highly fluidic space-time of general relativity. The space and time of a particle in empty space near matter are required to possess *very nearly* the same physical properties as of a particle remote from matter, so that, in particular, gravitational phenomena relatively to the particle are absent. It can not be and is not demanded that these properties are *exactly* the same. However, if the units of space and time selected are very small and diminished in the same ratio, so that very rapidly running clocks and very small measuring sticks are used, a Lilliputian universe results. In this universe gravitational phenomena disappear, and the laws of space, time, of matter and electricity, will be those of the special theory of relativity already considered, and the same for every reference particle.

The spatio-temporal system of any particle becomes of less and less consequence for more and more remote events. For this reason, if a well-balanced view of the physical universe is sought, it does not appear desirable to regard these individual spatio-temporal reference systems as of unusual importance. In other words, the selection of a reference system becomes to a large degree arbitrary.

It is in this fluidic property of the general theory that its difficulty resides. Near any particular event in space and time, experiments may be carried out with security at any small freely moving body; local distances, lapses of time, densities, pressures, temperatures, etc., may be treated by the usual methods, applied as if the body were at rest. The general laws of each microcosmic part will be those of the special theory, and yet there will be a slight macrocosmic deviation, caused by the presence of matter and the resultant curvature of the four-dimensional space-time continuum. Gravitational phenomena appear as only the direct manifestation of this curvature.

It is extremely natural from a philosophic point of view to require matter to condition space-time, for the physical determination of space and time is always through the intervention of matter.

A still more fluidic framework of space and time, based on the notion of "affine connection," has been introduced by Weyl, and developed much further as the "geometry of paths" by Eisenhart and Veblen. Recently it has formed the principal basis of attempts at even more complete unification of physical law by Eddington, Weyl and Einstein.

The general relativity of Einstein is connected with his special optical relativity, the mechanical relativity of Newton, and the geometrical relativity of Euclid in a very interesting way.

Suppose that we consider the general theory when matter is very sparsely distributed. Then the framework reduces to that of empty interstellar space, and the small gravitational effects noted will be those appropriate to the special theory or will be negligible. The principles of optical relativity will hold.

Now suppose, furthermore, that matter and electricity are moving with such low relative velocities that the velocity of light may be taken as infinite by comparison. Then, according to the general theory, electromagnetic phenomena disappear, and the *régime* of the mechanical relativity of Newton sets in, and his law of gravitation will be valid.

If also the rotational velocities and internal pressures are so small that to all intents and purposes material bodies are continually in undisturbed motion, the geometrical relativity of Euclid holds.

The mathematical working out of the new theory is not a simple affair, despite the simplicity and unity of the fundamental point of view which has led to it. This is not at all different from the circumstances attending previous theories in classical physics, for example, the theory of elasticity. Thus, ordinarily the tuning fork is considered to be a rigid body. It is only in this way that it is visualized with any success. However, the very property which makes it a useful instrument is that, when struck sharply, it will vibrate and communicate its elastic vibrations to the air, and thence to the eardrums, and excite the sensation of a musical sound of definite pitch. The manner in which it vibrates is exceedingly complicated, and varies according to the way in which it is struck, although experiment shows that the pitch of the fundamental note is not thereby perceptibly altered. The determination of the exact mode of vibration of its several parts has never been made. Although theoretically possible by means of sufficiently extensive computation, provided the tuning fork is idealized as a so-called perfectly elastic body, yet it is to all intents and purposes impossible of accomplishment. It is not even possible to explain its general behavior save by elaborate theoretical considerations, nor to specify the fundamental note in advance by any formula. And, if it were desired to deal directly with the assemblage of atoms and electric charges constituting it in actuality, the vibrational properties would appear as average effects of enormously complicated interactions of very large numbers of elements. Hence, even here, the reality is found to be so complicated as to be beyond the power of man to conceive adequately.

Simplicity and unity in the fundamental processes and yet an infinite complexity in their combinations seem more and more to be clearly manifested in nature.

Is the Einstein synthesis in any sense ultimate? That may be held to be exceedingly doubtful. The special model of interstellar space empty save for point particles, with which Einstein begins, is not a correct one, since there do not appear to exist point particles, but merely smallest elements, called atomic nuclei and electrons. Without a true model as a starting point, it does not seem likely that a final conception of the physical world can be arrived at by a process of generalization. The advances in recent years in the domain of physics indicate that we are just beginning to discover the laws of the atom. In fact, we have been compelled to proceed from the evidence of our senses, and thus have observed laws which are the statistical effect of inconceivably numerous elementary processes hitherto beyond our ken.

His new theories are a great step in advance, for they bring together in a remarkable way the laws of nature so far obtained. In them, gravitation appears as the law of macrocosmic interconnection, caused through curvature of space-time by matter, while the spatio-temporal relativity of non-gravitational laws is maintained in the microcosmic domain.

TWO EMBRYOS FROM ONE EGG[1]

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EXPERIMENTAL embryology, or, as it is better known, developmental mechanics, started on its class-conscious career about thirty-five years ago, and its infancy is remembered chiefly for two events. The first of these was Roux's discovery (1888) that a half embryo develops from one of the first two blastomeres (cells) of the frog's egg when the other blastomere is injured but present. The second was Driesch's discovery (1891) that a whole embryo develops from each of the first two blastomeres of the sea urchin's egg when they are separated from each other. The latter discovery was followed by a study of the eggs of other animals and led to the apparent paradox that in some animals a whole embryo of half size develops, and in other animals a half embryo develops from each of the isolated blastomeres. These results were idealized as two contrasting schemes of development, and far-reaching philosophical speculations were based upon them. Echoes of the controversy that followed may be heard to-day, although interest in them appears to be on the wane. Novel as were the results themselves, it must be admitted that they have not led to the solution of any of the fundamental problems of development. They served, however, a useful end in calling attention once more—for His had attempted to do this already in 1874—to the scientific problems of embryology from which students of embryology had been diverted since 1859 by over-attention to the historical side of the subject. It is not my intention to enter here into the conflict of opinion that arose between vitalist and mechanist, for even were there any profit in doing so, which I doubt, my object is to review the facts from a different angle rather than to raise philosophical and controversial questions.

It has been found that the isolated blastomeres of sea urchins, of certain hydroids, of a nemertean, of amphioxus, of a fish, of triton and of the frog give rise to whole embryos;[2] while the isolated

[1] Chapters from Experimental Embryology, V.

[2] Kleinenberg ('78) described a process taking place in an earthworm's egg at the end of cleavage by which two embryos result from one egg, or else two embryos partially united (twins). Vejdovsky ('88) has also described the development of twin embryos from the eggs of the same earthworm (*Lumbricus trapezoides*). A reexamination of this case is desirable. There are some features in the development of these eggs that suggest the possibility that its peculiarities may be due to the earlier fusion of two eggs with subsequent separation into two parts as the cleavage progresses. If this should prove to be the case the outcome would not be so difficult to bring into line with other results.

blastomeres of ctenophors, molluscs and ascidians give rise to half embryos. Before attempting to discuss whether or not there are any peculiarities in the development of these types that furnish any hint as to why in the one case whole-development takes place, and in the other half-development, it will be profitable to pass in review a few typical instances of each kind, because we shall find that the differences are not as sharp as is generally supposed.

One negative conclusion is, however, obvious, namely, that there is no relation between the systematic position of the animals, whether "high" or "low" in the scale, and the mode of development of their isolated blastomeres; for there is a hydroid and a vertebrate in one group, and a ctenophor and an ascidian in the other.

The Development of Whole Embryos from Isolated Blastomeres

The sea urchin was the first type in which it was shown that isolated blastomeres produce whole embryos. Driesch ('91) shook apart the blastomeres and followed their development. The method that he used to separate the blastomeres was one that had been earlier made use of by O. and R. Hertwig. They found that if the eggs of the sea urchin are violently shaken a few times in a small tube, half-full of sea water, the eggs may be broken into pieces. These pieces soon round up into small spheres, and if sperm is added some of the fragments segment. This same method, with one modification, was used by Driesch to separate the first two blastomeres.

If the sea urchin's eggs are fertilized and then after a minute or two are gently shaken, so that they are not broken, the fertilization membrane that has formed at the moment the sperm pierced the surface of the egg is shaken off the egg. This procedure makes the subsequent separation of the two blastomeres, when the egg has divided, quite easy. This separation is brought about by again shaking the eggs when at the height of their division. The isolated blastomeres are then picked out for further study. Each continues to segment as though in contact with its fellow. The cleavage is strictly partial (Fig. 1, a^1, b^1, c^1). In other words, each half divides as it would have done had it remained in contact with its fellow. (Fig. 1, a, b, c).

In the normal development a cavity appears in the center of the group of dividing cells. It first appears at about the eight-cell stage and grows steadily larger as the divisions proceed. A cavity also appears in the group of cells from the isolated blastomere, but it is at first exposed to the exterior on one side. Later the cells

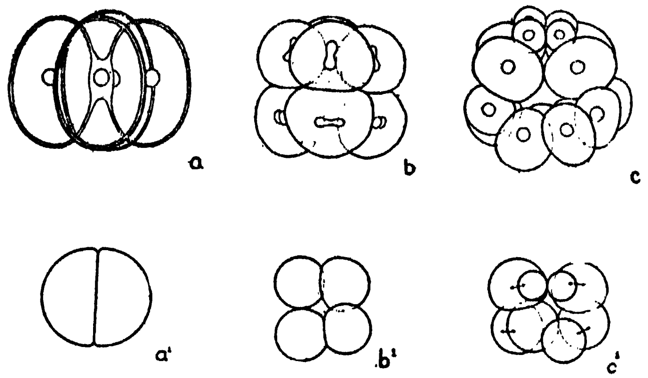


FIG. 1

around the margin of the open cavity move over it so that it soon comes to lie in the center of the group of cells as in the normal embryo. At the time when the cleavage process has temporarily slowed down, and the cells have become ciliated (blastula stage) the half-embryo resembles in all visible respects the normal embryo of the same age—except in size. If the number of its cells is counted, it will be found that half as many cells are present as in the normal embryo of the same age, and that the cells and nuclei have the same size in both. In this respect the half-embryo is not proportionate, since its cells are relatively twice too large. Half as many mesenchyme cells are present in the half-gastrula as in the normal, and each cell is as large as in the normal embryo. The turning in at one pole, to produce the gastrula stage, takes place in the half-embryo (Fig. 2, b) in the same way as in the normal embryo (Fig. 2, a). A pluteus of half-size (Fig. 2, b^1) develops that is like the normal (Fig. 2, a^1) in all its characters.

The isolated blastomeres of Amphioxus also produce whole embryos (Wilson '93, Morgan '96). The eggs in the two-cell-stage can be easily shaken apart without rupturing the jelly that surrounds the eggs, and since the interior of the jelly is a large fluid space, the two isolated blastomeres of the same egg may both be kept under observation. The halves develop into whole embryos of half size (Fig. 3, b, b^1), although, as in the sea urchin also, the cells are as large as in the normal embryo, but only half as numerous.

In triton the results are in part the same as in Amphioxus, in part different. The first cleavage plane of some eggs corresponds to the median plane of the embryo. If the blastomeres of such eggs in the two cell stage are constricted by means of a loop of hair tied around an egg in the plane of cleavage and later tightened so that the halves are separated (Fig. 4, a), the halves will develop each into a whole embryo (Fig. 4, b, b^1) (Herlitzka '96, Spemann

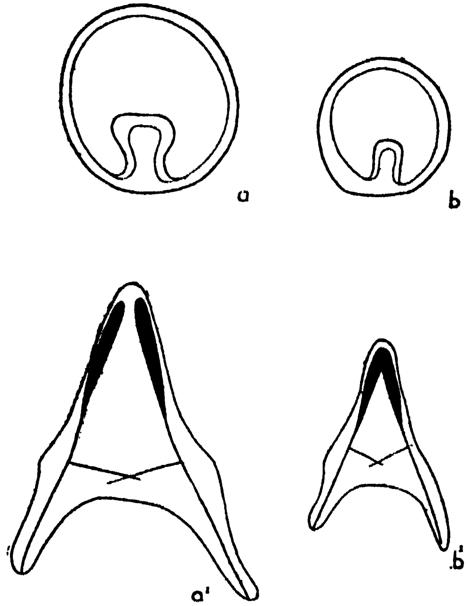


FIG. 2

'01, '03). In other eggs of triton the first plane of cleavage is at right angles to the median plane of the body of the embryo. It corresponds approximately to an imaginary cross-plane between the anterior and posterior halves of the embryo. If a loop of hair is tied around such an egg in the plane of the first cleavage and tightened until the two blastomeres are gradually separated, the halves give different results. From one blastomere, that may be called the anterior one, a whole embryo develops, or at least one that approaches a whole embryo. From the other blastomere, the

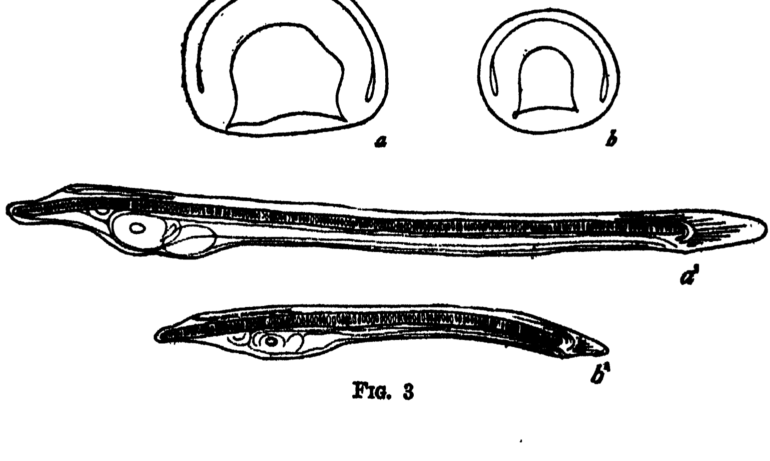
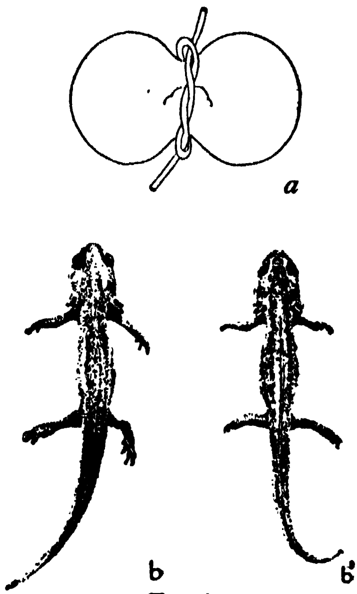


FIG. 3



a b b'

Fig. 4

posterior one, there develops a structure that to some extent resembles the earliest stages of the posterior half of a triton embryo, but it develops no further.

The differences in the results just described are significant and help us to understand in one respect at least the more general differences shown between those eggs that give whole embryos from isolated one half blastomeres and those that give half-embryos. Here, from one and the same egg, both results happen according as to whether the first plane of cleavage does or does not correspond with the median plane of the body that is foreshadowed in the first division of the egg. It will be worth while, therefore, to examine this case somewhat more in detail.

It is very probable that at the time of fertilization changes take place in the triton egg that are like those known to take place in the frog's egg. In the latter, extensive movements of material occur that become visible on the surface by the development of the so-called gray crescent. This crescent appears near the equator of the egg and indicates the position on the egg where the dorsal lip of the blastopore will later develop. It is through the center of this crescent that the first plane of cleavage of the frog's egg passes. The crescent is visible, owing to a shift in the pigment that lies in the protoplasm beneath the surface. If the pigment were less in amount, or more superficial, the shift in the protoplasm might pass entirely unnoticed. If these same changes take place in triton, it is

possible to give a plausible account as to why a different result follows when the first plane cuts through the crescent (as it does as a rule in the frog), and when it cuts the egg in two at right angles to this plane as it often does in triton. Let us consider each case separately. When in triton the first plane of cleavage cuts the imaginary crescent into symmetrical halves each half has half the crescent. The crescent is the initial point around which the subsequent development takes place. Each isolated blastomere has half of this region around which the subsequent changes take place. Some sort of readjustment must occur in such halves either before or at the time of the formation of the dorsal lip, so that the half material assumes a more symmetrical shape and becomes a whole or in other words a new median plane develops in the half crescent and whole development follows.

In the other case, where the first plane of cleavage of the triton egg is at right angles to the crescent, one of the isolated blastomeres contains all the crescent material and the other almost none of it. The former, having in itself the center for further development, proceeds to grow over the yolk and produces an embryo. The original median plane of the crescent becomes the median plane of this embryo. Readjustments to the size of the mass must take place because the embryo that emerges is not the anterior half of an embryo but a whole embryo of half size. The posterior blastomere, on the other hand, lacks the crescent, or at most has only the ends of its lateral wings; hence, lacking a center of development, it soon comes to a standstill.

This analysis, while superficial in certain respects, may help to make clearer the difference in the two cases under consideration. Viewed in this way, the development of the isolated blastomeres in the two types is not due to any fundamental differences, but to certain changes which have taken place in the egg before the first cleavage occurs—changes that have an important bearing on the future possibilities contained in different parts of the egg.

The Development of Half-Embryos from Isolated Blastomeres

The development of isolated blastomeres of the egg of an ascidian (Ascidiella) was described by Chabry as early as 1887. He accomplished his purpose by puncturing one of the blastomeres with a fine glass needle carried on a micro-dissection instrument. The apparatus was so constructed that by means of screws the needle could be swung into any desired position and then pushed forward through the egg membrane and made to pierce a selected cell. The punctured cell absorbed water, swelled up and died. The needle was withdrawn and the development of the remaining cell or cells was studied.

Chabry pointed out that the developing blastomere produces the same parts of the embryo that it would have produced had it remained in contact with its fellow. He realized the practical value of his method as the following statement shows:

There are two methods by which the lineage of a blastomere may be discovered, the first by direct observation, the second by destroying a blastomere. Both have led me to the same result but the former is limited in its application while the second is rapid and more generally applicable. In this way I have determined with certainty that the eye is a product of the right anterior cell of the four-cell stage and I have found similar evidence for other organs—the otolith, the notochord, the atrium and the adhesive papilla. However, a secondary effect enters in to disturb the simplicity of the method but constitutes in itself an important phenomenon that calls for new experiments. It is, in effect, that by the death of a cell the potency of the survivors is changed so that they may give rise to parts which they do not otherwise produce.

Chabry's figures of the larval tadpoles that develop from the one half and three fourths blastomeres look like whole embryos in most respects. They do not show, as have later studies, that the tail muscles and mesenchyme are lacking on one side, which is to-day regarded as the most diagnostic feature of the ascidian half-embryo. On the other hand, Chabry pointed out that the adhesive organs and atrium are present only on one side. These are as distinctively bilateral structures as the musculature of the tail.

Several years later Driesch ('95) studied the development of isolated blastomeres of another ascidian (Phallusia) and interpreted the resulting embryos as wholes. He supposed that Chabry had also obtained whole embryos. Crampton ('97) also examined the isolated half-blastomere of an ascidian (Molgula) and found that the cleavage is strictly partial but somewhat obscured by the rearrangements of the cells. He concluded that Driesch was entirely correct in regard to the development of a nearly complete larva from the half-blastomere.

The later work of Conklin ('05) on still another ascidian (Styella), proved beyond question that Chabry's interpretation of the larvae as part structures was essentially correct. Conklin followed in greater detail the cleavage of the isolated blastomere, and showed that it is partial (Fig. 5, c). He made out that the cells give rise to the same parts (Fig. 5, d) that they produce in normal development (Fig. 5, b). His results also show, as had the earlier observations, that the embryo is not in all respects a half-structure. Several of the organs are, in fact, not far from whole structures. For instance, the digestive tract is a closed tube, not quite symmetrical, perhaps, but nearly so; the nerve cord is a closed tube lying in or very near the middle line, and the notocord, as in the

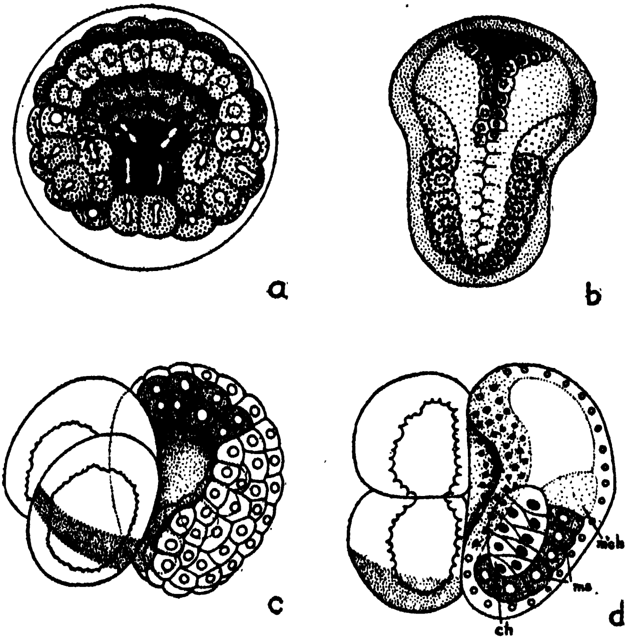


FIG. 5

normal embryo, consists of a single row of cells; it forms, in fact, a whole structure. The mesoderm of the tail (Fig. 5, d, ms), however, that is lateral to the neural tube and notocord is strictly a half-structure. From the mode of origin of its cells it would not be easily possible for the mesoderm to pass over to the other side. The atrium and the adhesive discs are also half-structures in the sense that they are present only on one side as Chabry had observed, although each is of course as complete in itself as in the whole embryo. It may be said, therefore, that, while a half-embryo develops from the isolated blastomere of the ascidian egg, there is nevertheless an evident approach to whole structures of half size in three of the important systems of the body. In these latter respects such embryos would pass for wholes were not the half-structures of more lateral organs in evidence.

Chun ('77) found in the plankton a few embryos of the ctenophor, Eucharis, within the same egg membrane, each of which had four rows of paddles (instead of eight) and one tentacle instead of two. He surmised that they had arisen by the separation of the first two blastomeres through agitation of the waves and that each cell had given rise to a half or nearly half-embryo. He established his supposition ('92) by shaking eggs of Eucharis while in the two cell stage.[3] A few years later the experiment was repeated by

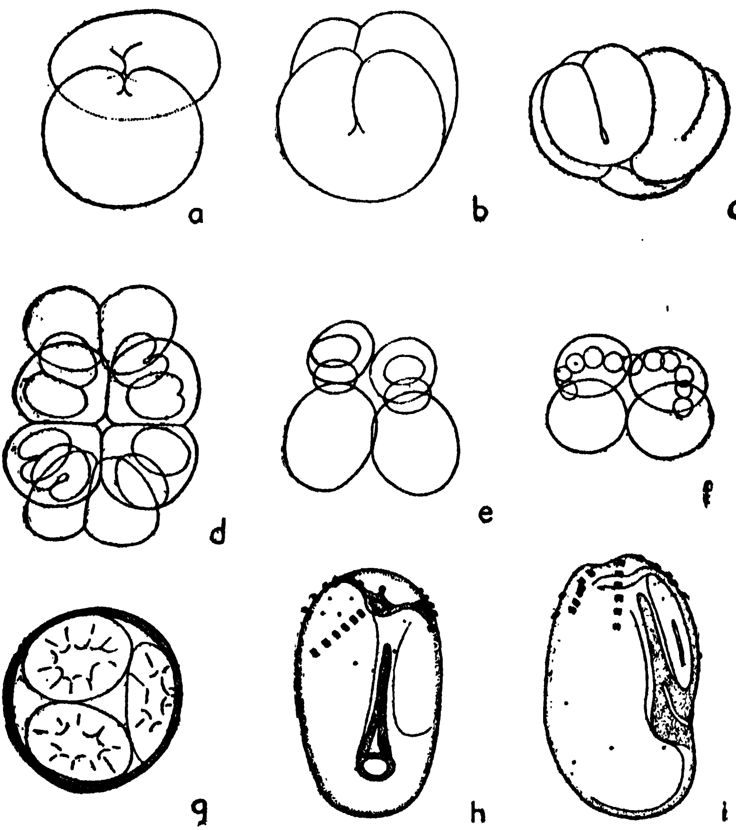


Fig. 6

Driesch and Morgan ('95) with the larger egg of another ctenophor, Beroe, and half embryos were also obtained from this egg.

The early cleavage stages of the normal egg of Beroe are shown in Figs. 6, a–d. The egg divides into two equal cells. Each cell again divides in a plane at right angles to the last. The third division is somewhat oblique, giving rise to 8 cells that are nearly in one plane (Fig. 6, c). Then from each of the 8 cells a small micromere is given off (Fig. 6, d). It is from derivatives of these 8 micromeres that the 8 rows of swimming paddles develop. This has been shown by removing one or more of the micromeres or by displacing them with respect to the other cells (Fischel ('98) Yatsu ('12)). The results show that even at the two cell-stage certain changes have taken place that proceed in each half as though it were independent of the changes going on in the other half.

[3] Roux's half-embryos of the frog ('88) had developed in the presence of the other injured half, and the results were undoubtedly affected by the presence of the injured blastomere, as his results indicated and as later results have proven.

It was further shown by Driesch and Morgan, and later confirmed by Fischel ('98) that the ctenophor half-embryo is somewhat more than a half structure (Fig. 6, g, h, i). The ectoderm, for instance, covers the whole surface; there is a single tubular esophagus somewhat excentric in position, and instead of two gut-pouches (i.e., half the normal number), there is a smaller third pouch generally present. Whether the apical sense organ is something more than a strict half was not determined. But with these reservations the embryos from the isolated blastomere may be said to represent in certain striking respects a half structure.

The isolated blastomeres of four molluscs have been studied; Crampton ('96) has studied the isolated blastomere of Ilyanassa, Wilson ('04) that of Dentalium and of Patella, and Conklin ('05) that of Crepidula.

The normal egg of Ilyanassa divides into two nearly equal halves (Fig. 7, a, b). A yolk lobe (yl) appears in one of the blastomeres (CD) as the first division is taking place. When this blastomere is isolated it cleaves as part (Fig. 8, a, b, c, d) and later produces the primary mesoderm cell (Fig. 7, f, d^4), while the opposite blastomere, AB, when isolated (Fig. 8, e, f, g, h,) fails to produce this cell. It is to be expected, therefore, that the former might produce an embryo much more nearly whole than the latter that lacks this important cell from which nearly all the middle layer organs develop. The half embryos of Ilyanassa died, however, without passing beyond the later cleavage stages, so that the characters of the two embryos are not known.

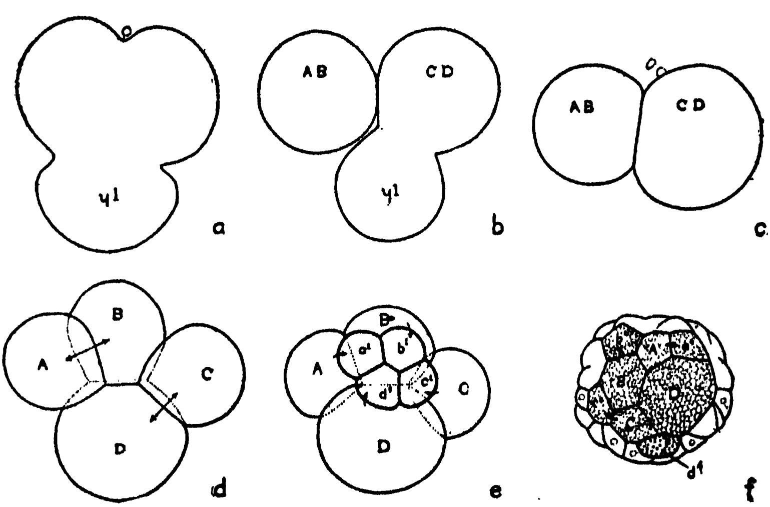


FIG. 7

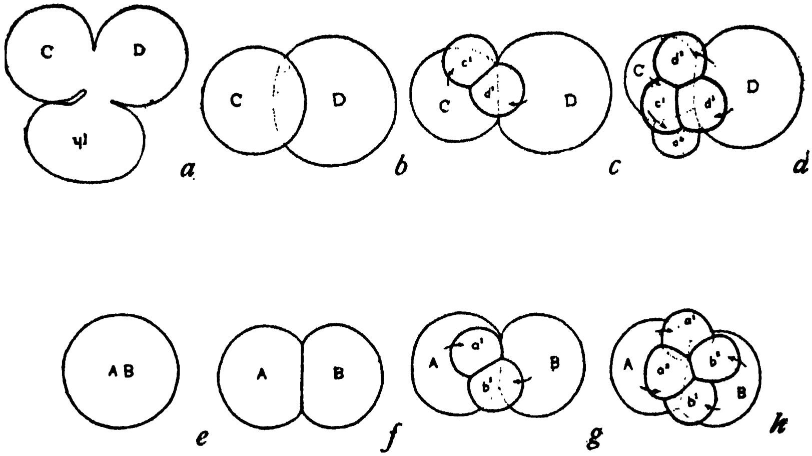


FIG. 8

In Dentalium the fate of both the CD and the AB blastomeres has been followed somewhat further. The normal cleavage is shown in Fig. 9 a–f; that of the isolated CD blastomere in Fig. 10 a–f; and that of the isolated AB blastomere in Fig. 11 a–d. The normal swimming larva (trochophore) is shown in Fig. 12 a, b; the half embryo from the CD blastomere in Fig. 12 c; and the half embryo from the AB blastomere in Fig. 12 d. Wilson ('04) found that both the AB and the CD isolated blastomeres (Fig. 10 and Fig. 11) cleave as parts, *i.e.*, each as though still in contact with its fellow. Each gives rise to a swimming larva, but the two differ in

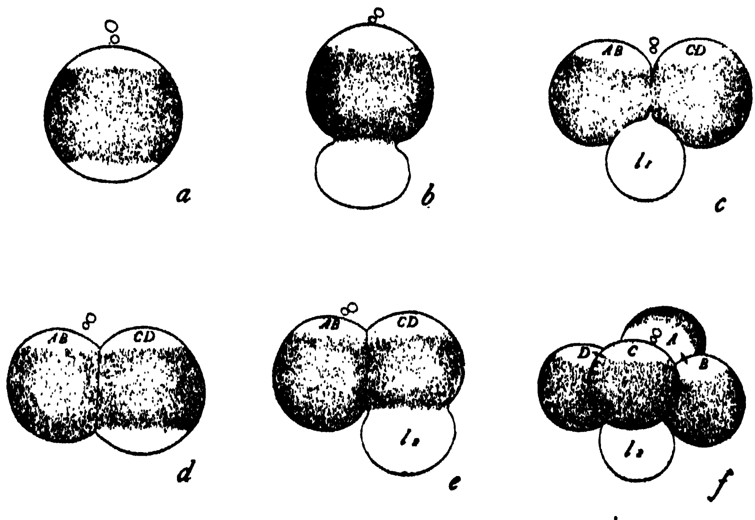


FIG. 9

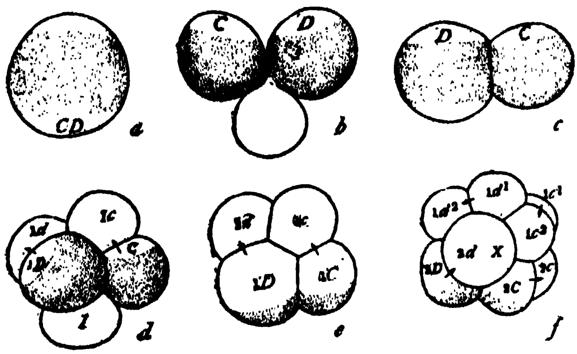


FIG. 10

certain respects. The AB larva lacks (Fig. 12, d) the apical tuft of cilia, whose presence is in some way connected with the presence of the yolk lobe. The CD larva (Fig. 12, c) has an apical tuft. The AB larva also lacks the region behind the circle of ciliated cells. How far its absence is due to the absence of the d^4 cell, directly or indirectly, has not been shown. The CD larva has a post-trochal region. Superficially, at least, it is not partial but complete, but as yet we do not know whether the mesoderm derived from the 4d cell forms a symmetrical or an asymmetrical structure inside of this embryo. Outwardly at least, the CD embryo approaches a whole larva of half size, but if we apply to this case the same criteria that have been insisted upon in the case of the half-ascidian embryo we should be obliged to confess that we do not know whether the half Dentalium CD trochophore is a half or a whole structure. Much less could it be said that the AB trochophore is a whole embryo if it lacks all the mesoderm normally derived from the 4d cell. The conventional distinction between whole and half embryos has here very little meaning, owing to the unilateral origin of the mesoderm that comes in the normal embryo only secondarily to have a right and left distribution.

The Development of the Half Blastomere when left in Contact with its Injured Partner

The experiment that Roux ('88) carried out by injuring one of the first two blastomeres of the frog's egg and the conclusions that

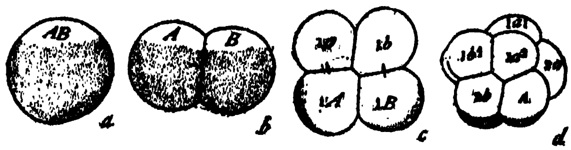


FIG. 11

he drew from the results occupied the forefront of the earlier discussions concerning developmental "mechanics." The later experiments of the same sort by Endres and Walter ('95), Morgan ('04) and Brachet ('05) have confirmed Roux's main result, while other somewhat different experiments by Schultze ('94), Wetzel ('95) and Morgan ('95) have led to conclusions that are very different from those that Roux reached from his evidence.

Roux stuck one of the blastomeres with a hot needle. Its development was for a time delayed or entirely suppressed. The other, uninjured blastomere continued to develop as though the injured half were also proceeding along the same path. A half-blastula stage (Fig. 13, A) followed by a half or nearly half embryo developed in intimate contact with the injured half (Fig. 13, B). Similar embryos have also been reported by Endres and Walter, by Morgan and by Brachet, and even some of those described by Oscar Hertwig are obviously of the same sort, despite the fact that Hertwig gave a different interpretation to them as well as to all embryos that develop under the conditions of this operation (see below).

There are three questions connected with Roux's experiment that call for further discussion; first, as to whether the embryo is more than half; second, as to whether the result is due to

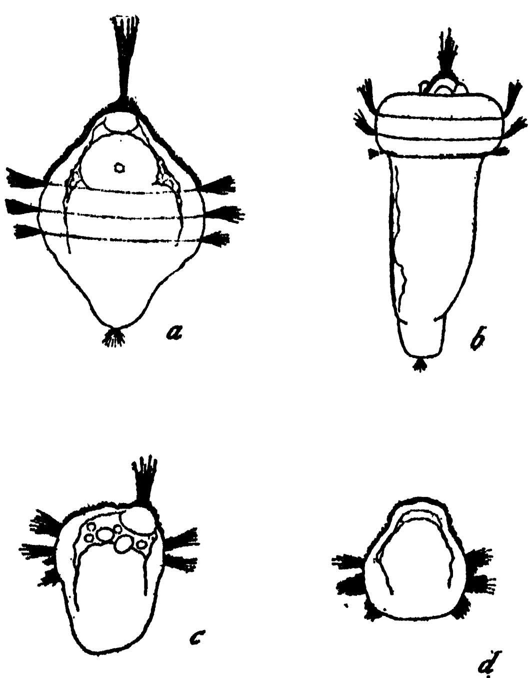


FIG. 12

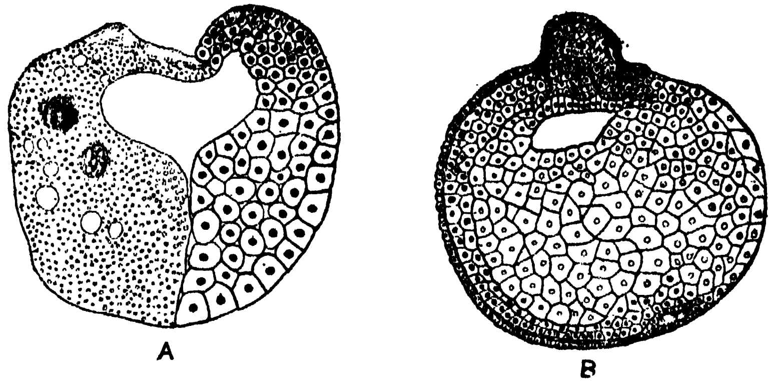


FIG. 13

the injured blastomere remaining alive; third, as to whether the injured half may at times partially develop.

(1) That the head end of the embryo is often more than a half structure is shown by several of the drawings of the embryos. Nevertheless, the rest of the nerve plate is much more nearly a half than a whole structure and from the method of the early formation in a lateral position this is perhaps to be expected. The notochord is circular in outline and may well be spoken of as a whole structure. The anterior end of the digestive tract also approaches in some respects a whole structure, although the block formed by the injured half appears to interfere with its completion. In other respects, especially in relation to the mesoderm, these embryos are practically halves.

(2) Both Hertwig ('93) and Morgan ('97) have challenged Roux's treatment of the injured blastomere as though it had been killed by the hot needle, although it should be added that when describing the subsequent changes in that blastomere, Roux recognized that it is still alive except for the streak of necrotic tissue along the path of entrance of the needle. A study, by means of sections, of the injured blastomere shows that in many of them the nucleus has not been injured; that it may subsequently divide, and that portions of the cytoplasm may split off from the rest and add themselves to the uninjured half, and in extreme cases the delayed blastomere may even catch up and produce its half. Owing to the opacity of the egg, it is not possible to follow continuously what takes place and at best the history can only be pieced together. Aside from these details the evidence shows positively that the uninjured half is alive and in intimate contact with the other half. This condition raises a series of further problems as to the possible influence of the injured on the developing half. If the unsegmented

half *remaining in its normal position* can exert the same sort of influence on the developing half as it would exert were it also dividing, the experiment tells nothing more than what was already known from the earlier observations showing that the material on one side of the first cleavage plane gives the right half of the embryo and that on the other side the left half. Other experiments to be described in a moment show that this is probably the case, but the nature of the influence remains as obscure as before.

(3) Roux has described under the name of post-generation changes that take place in the injured half by means of which the missing half may be later replaced. The account of these changes is obscure in many important respects, and necessarily so since it is gained by patching together the evidence of sections from different eggs no two of which may have had the same antecedents. My own view of the matter is that whenever the missing part reappears its development must come very largely from the delayed development of the injured blastomere. A discussion of these difficulties of interpretation would require here too much space and the conclusions would not affect the main issues under discussion.

Oscar Hertwig has given an entirely different account of what occurs where one blastomere is injured by Roux's sticking method. In a word, he thinks that the uninjured blastomere develops as a whole, except when the injury is so slight that part of the other blastomere becomes incorporated in the uninjured half. The injured blastomere, he states, holds the same relation to the developing half as does the yolk to the embryo of a meroblastic egg. In other words, a whole embryo develops with an uninclosed ventral yolk. That something like this may at times really take place is possible, I think, in the light of the other evidence given below, but I also think the comparison with the meroblastic egg is entirely misleading. If, after the operation, the egg is so placed that the uninjured blastomere lies on top of the other, then, through the rotation of the protoplasm in the interior of this blastomere, the conditions are such, as shown by other evidence, that a whole embryo, so far as the physical conditions allow, may develop from the uninjured half. In so far as the rotation of the protoplasm is incomplete, all degrees of part and whole embryos may result and the internal evidence in Hertwig's paper points clearly to some such interpretation.

Later observations have shown that each of the first two blastomeres of the frog's egg may produce a whole embryo provided the influence of the other half is changed or removed.

It was shown by Schultze ('94) that if the egg in the two-cell stage is turned over so that the white hemisphere is on top, and if

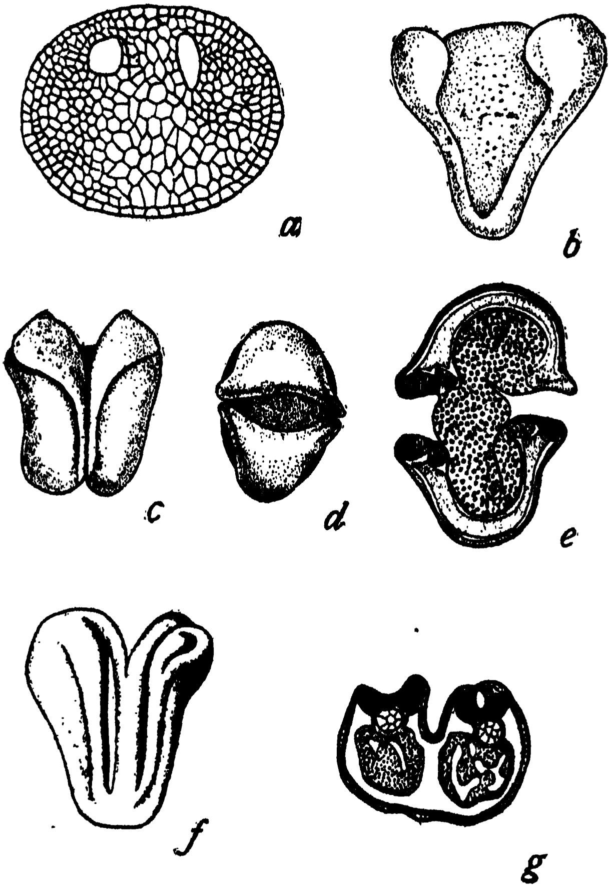


FIG. 14

the conditions have been so arranged that the egg can not turn over to its normal position with the black hemisphere above, then two whole embryos develop, one from each half. Sometimes these embryos lie side by side, (Fig. 14f) like Siamese twins. At other times they are united in their ventral surface (Fig. 14b), and at other times they are back to back (Fig. 14c, d, e). In the last, the halves are prevented from coming together by the yolk. Each embryo shows, in consequence, a spina bifida condition (Fig. 14e). Wetzel ('95) has given an account of the changes that take place in the inverted egg. In each blastomere the lighter protoplasm, now below, tends to move upward and the yolk to sink downward. The path taken by these components will depend on slight differences in the inclinations of the egg, and, correspondingly, the embryos that result will be diffierently placed in different eggs.

Each half develops independently of the other, so far as the physical conditions permit; each develops its own planes of symmetry and produces a whole embryo of half size.

The upshot of all this evidence is, that if like regions of the two eggs are separated they no longer act together as parts of a whole. This conclusion, if applied to Roux's half-embryo, may be interpreted to mean that the development of a plane of symmetry is influenced by the juxtaposition of similar protoplasmic fields, but unfortunately the evidence fails to reveal whether this is a chemical influence or only due to physical contact.

That each blastomere of the frog's egg may produce a whole embryo has been shown by experiments of Morgan ('95) and McClendon ('00). The former found that if, after injuring one blastomere with a hot needle, the two blastomeres are kept in their normal position with the black hemisphere up, a half-embryo develops. But if, after sticking, the egg is turned so that the uninjured cell is on top it gives rise to a whole embryo. McClendon ('00) found that by the combined action of a pipette and careful sticking with a cold needle it was possible to remove entirely one of the first two blastomeres of the egg of the tree frog, Chorophilus. The remaining blastomere produced a whole embryo. The operation is not possible on most species of frogs, so far tried, because the removal of the contents of one blastomere causes the other to collapse.

Conclusions

It is with some hesitation that I venture to express a personal opinion as to the interpretation of the results of the experimental work on isolating blastomeres. I find nothing in them that is particularly mysterious, *i. e.*, nothing that we may not hope in time to explain mechanically. In fact, it seems rather obvious that both whole and half development proceeds along lines that have already taken place in the preceding stages. The blastomere when isolated does not suddenly become a whole, but, as the successive stages appear, they are modelled on what has already taken place as in the normal development. Those readjustments that lead to whole organs instead of partial structures appear to involve only the same processes that take place in whole embryos in the same stages. This is particularly evident in organs that lie in the middle line. Those that are to one side of the middle line may continue their regular course of development and call for no special explanation.

This pioneer work is rather exploratory than experimental. It has been carried far enough, however, to make it seem doubtful whether we have much more to expect from a continuation of the

work along the old lines. We need for further progress to find out the physical and chemical nature of the material that causes it to take on, as each phase of development is reached, definite symmetrical patterns. The biological analysis has, for the moment, reached its goal, and the problem is ready to hand on to the physicist. We can now, I think, with profit throw into the discard the whole transcendental philosophy that has been used in describing the facts. Such terms as self-differentiation and interaction of the parts, prelocalization of cytoplasmic areas, prospective potency and the like, did no particular harm so long as it was realized that they were only names for certain observed facts, or inferences from the facts; but in so far as these expressions did not refer the phenomena to simpler or better known processes or principles, their use has played directly into the hands of the vitalist, for these words do not suggest anything with which a physicist or chemist is familiar.

ANTONI VAN LEEUWENHOEK, IMMORTAL DILETTANT (1632-1723)[1]

By Dr. L. B. BECKING
STANFORD UNIVERSITY

THE microscope was invented and man began to observe strange things; the shores of a new world. At first he saw only dim and distant shadows, projected vaguely upon his consciousness. Like "the living atoms of the world" those shadows trembled before man's vision, whirled and fled.

The few that were able to look through that small magic window, the lens, felt that their eyes had seen wonders. They toiled to make these shadows into realities; until at last they were able to see them clearly—the inhabitants of a world within our world—the citizens of the microcosm.

Structure within structure, they realized, was a new expression of eternity.

Fate had decreed that a revelation of this world should come to a man of mediocre mind, but with marvellous hands and keen eyes. A humble lens-grinder, at the service of too many intellects, he laid down his observations as he made them, in a series of incongruous, chaotic, but truthful observations. Incredibly truthful observations. For few are wholly able to withstand the temptation to interpret the results according to expectations.

Truly he was a pair of eyes, a pair of hands, directed by other minds. For when his own mind tried to direct, he could produce nothing but chaos.

His work is very little appreciated because little read in the original. This is perhaps the reason why the existing biographical characterization of the man and his work give an entirely erroneous impression.

Biographers often see their subjects either too closely or from too great a distance. The account given by the loving self, the loving wife or the loving son-in-law can not but represent a carefully retouched portrait. On the other hand, the thorough but tasteless account of the historiographer describes a spectre, not a reality—an abstraction, not a vitality—the embodiment of an idea, but not the forces creating it.

[1] Lecture held for the Society of Experimental Biology and Medicine, October 26, 1923.

What really matters in a biography is not the so-called biographical datum. The attributes of a creature; its birth, its growth, its offspring, its death only express the fact that it was alive and kept in this precarious condition for some time, after which it went the way of all flesh.

Biographical data are only useful to coordinate the individual in his proper surroundings. That Leeuwenhoek was married twice, that he had many children, can be found, with many other delightful details, in one of his biographies. It does not concern us here.

Modern biographies also frequently mention hereditary factors. Is the heritage as important as it seems? Nothing prevented Pas-

teur, a tanner's son, from becoming the scientific aristocrat "par excellence" of his age. Nothing prevented Leeuwenhoek, a patrician's son, from developing into an uncultured mechanician.

There are factors, inherent in the race, that breed out and force themselves into the phenotype regardless of careful selection, regardless of parental influence. They appear at certain stages in the development of a homogeneous population and determine the character of the community.

Leeuwenhoek fitted well into the surroundings of the seventeenth century Dutch Republic. His influential relatives secured a position for him—in that age of nepotism—when at forty he had failed in life, when he had neither acquired learning nor money nor power to make himself esteemed by the burghers of his native town. He was made janitor or Bedellus of the sheriff's office at Delft.

Many comments have been made by biographers on the humbleness of his position. Even his contemporaries were properly impressed by it, especially his English fellow-members of the Royal Society. They were probably ignorant of the fact that the position was a sinecure, obtained by political graft and created as a source of income for one of the renegade sons of the governing families. But the position was important because it provided for ample leisure. While his presence at the office was required, he had practically nothing to do.

Leeuwenhoek belonged to a time when the mentally unendowed collected curios and shells, when the bulb fanciers tried to attach excessive importance to relatively unimportant objects, as stamp collectors do. There is a spiritual bond between collectors and creators-of-tiny-things. The collector wants to fill an emptiness that is within himself. Creators-of-tiny-things want to kill a threatening emptiness—time. People who wait, conducted by this "horror vacui," construct absurd things. They knit and knit, while they wait for the guillotine to fall. They adorn their books with curious ornaments while waiting for the end of a lecture hour. Railroad guards, around their shanties, construct elaborate doll-gardens, and Esquimaux during the long polar night carve little figures out of walrus-teeth.

Leeuwenhoek filled, and killed, his time with the grinding of lenses. During the dreary Dutch days, when rain drizzled outside, and chill must have pervaded his "comptoir" the dilettant was slowly preparing himself for immortality.

He stayed at Delft until his death, but still he can not be compared in this respect with Immanuel Kant, who never left Königsberg. Kant had created a universe within himself. For Leeuwen-

([illegible])

Obſervations, communicated to the Publiſher by Mr. Antony van Leewenhoeck, in a Dutch Letter of the 9th of Octob. 1676. here Engliſh'd: Concerning little Animals by him obſerved in Rain-Well-Sea- and Snow water; as alſo in water wherein Pepper had lain infuſed.

IN the year 1675. I diſcover'd living creatures in Rain water, which had ſtood but few days in a new earthen pot, glaſed blew within. This invited me to view this water with great attention, eſpecially thoſe little animals appearing to me ten thouſand times leſs than thoſe repreſented by Monſ. *Swamerdam*, and by him called *Water-fleas* or *Water-lice*, which may be perceived in the water with the naked eye.

The *firſt* ſort by me diſcover'd in the ſaid water, I divers times obſerved to conſiſt of 5, 6, 7, or 8 clear globuls, without being able to diſcern any film that held them together, or contained them. When theſe *animalcula* or living Atoms did move, they put forth two little horns, continually moving themſelves: The place between theſe two horns was flat, though the reſt of the body was roundiſh, ſharpning a little towards the end, where they had a tayl, near four times the length of the whole body, of the thickneſs (by my Microſcope) of a Spiders-web; at the end of which appear'd a globul, of the bigneſs of one of thoſe which made up the body; which tayl I could not perceive, even in very clear water, to be mov'd by them. Theſe little creatures, if they chanced to light upon the leaſt filament or ſtring, or other ſuch particle, of which there are many in water, eſpecially after it hath ſtood ſome days, they ſtood intangled therein, extending their body in a long round, and ſtriving to diſ-intangle their tayl; whereby it came to paſs, that their whole body lept back towards the globul of the tayl, which then rolled together Serpent-like, and after the manner of Copper- or Iron-wire that having been wound about a ſtick, and unwound again, retains thoſe windings and turnings. This motion of extenſion and contraction continued a while; and I have ſeen ſeveral hundreds of theſe poor little creatures, within the ſpace of a grain of groſs ſand, lye faſt cluſter'd together in a few filaments.

I alſo diſcover'd a *ſecond* ſort, the figure of which was oval; and I imagined their head to ſtand on the ſharp end. Theſe were a little bigger than the former. The inferior part of their body is flat, furniſhed with divers incredibly thin feet, which moved

very

REPRODUCTIONS OF TWO PAGES FROM THE ROYAL SOCIETY TRANSACTIONS, 1676, showing that Leeuwenhoek saw aerobic bacteria in pepper infusions. See H. W. Beyerinck, Verzamelde Geschriften, Vol. V, p. 127, 1922.

(828)

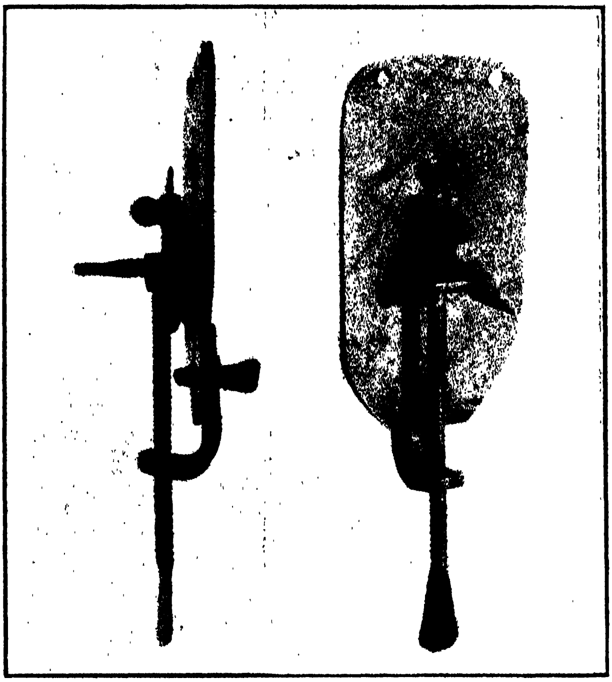
to my ſelf. This pepper having lain about 3 weeks in the water, to which I had twice added ſome Snow-water, the other water being in great part exhaled; I looked upon it the 24 of *April*, 1676. and diſcern'd in it, to my great wonder, an incredible number of little animals, of divers kinds; and among the reſt, ſome that were 3 or 4 times as long as broad; but their whole thickneſs did, in my eſtimation, not much exceed that of the hair of a Louſe. They had a very pretty motion, often tumbling about and ſideways; and when I let the water run off from them, they turned as round as a Top, and at firſt their body changed into an oval, and afterwards, when the circular motion ceaſed, they returned to their former length.

The 2d ſort of creatures, diſcover'd in this water, were of a perfect oval figure, and they had no leſs pleaſing or nimble a motion than the former; and theſe were in far greater numbers. And there was a 3d ſort, which exceeded the two former in number; and theſe had tails alſo, like thoſe I had formerly obſerv'd in Rain-water.

The 4*th* ſort of creatures, which moved through the 3 former ſorts, were incredibly ſmall, and ſo ſmall in my eye, that I judged, that if 100 of them lay one by another, they would not equal the *length* of a grain of courſe Sand; and according to this eſtimate, ten hundred thouſand of them cou'd not equal the dimenſions of a *grain* of ſuch courſe Sand.

There was diſcover'd by me a fifth ſort, which had near the thickneſs of the former, but they were almoſt twice as long.

2. The 26*th* of *April*, I took 2½ ounces of Snow-water, which was about three years old, and which had ſtood either in my Cellar or Study in a Glaſs-bottle well ſtopped. In it I could diſcover no living creatures. And having poured ſome of it into a Porcelain Thea-cup, I put therein half an ounce of whole pepper, and ſo placed it in my Study. Obſerving it daily until the 3d of *May*, I could never diſcover any living thing in it; and by this time the water was ſo far evaporated, and imbibed by the pepper, that ſome of the pepper-corns began to lye dry. This water was now very thick of odd particles; and then I poured more Snow-water to the pepper, until the pepper-corns were cover'd with water half an inch high. Whereupon viewing it again the fourth and fifth of *May*, I found no living creatures [illegible], but the [illegible] did very many, and thoſe exceeding ſmall ones.



FACSIMILE COPY OF THE ORIGINAL "MICROSCOPE"
in the possession of the Zoological Institute, Utrecht, Holland. Obtained by the courtesy of Dr. H. F. Nierstrasz. With this (or a similar) instrument Leeuwenhoek's chief discoveries were made.

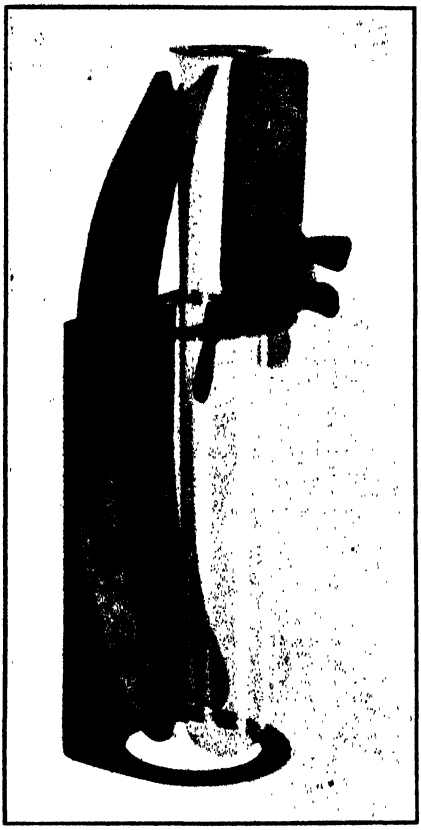
hoek, the marshes and meadows around Delft were amply sufficient. For Kant, the earth was too small to bother with. For Leeuwenhoek it was too vast.

Strangely undisturbed by the wars that raged around him, by political upheavals, by economic disasters, we find no mention of such things in his work. In this regard he had elements of a true scientist. Science has never been concerned with the influence of the rabble or the politicians. Already seventeenth century science had its own sphere, and quietly prepared to make our civilization.

His kaleidoscopic work was pioneering—he took the first harvest from a virgin field. But he gathered only the things that appealed to his fancy, no distinct line of thought can be found in his researches.

And, therefore, although he was the first to see bacteria, yeasts and protozoa, we can not look upon him as the founder of microbiology.

Although he was the first to describe crystals of piperin and caffein, prepared by sublimation, still Leeuwenhoek can not be called the founder of microchemistry.



Facsimile of the Circulation Microscope,
with which Leeuwenhoek studied capillary circulation. This microscope was designed to study the eel's tail.

Although he describes a butyric acid fermentation in a partly evacuated tube—Pasteur is the discoverer of this fermentation, and not Leeuwenhoek.

It is only the genius that can synthesize a vast group of disconnected facts under a general law, where the truthful observer only can describe and catalogue. In that respect Leeuwenhoek did not reach the mental level of a taxonomist; his descriptions were not catalogued.

It is almost impossible to form an adequate idea of this man. This strange personality—dusty as an ancient apothecary, common to a degree, erratic, uncultured, and still, by virtue of his work, chosen to be the spiritual associate of a Huygens, a Malpighi, a Swammerdam.

The uncritical praise of his commentators and biographers can only be ascribed to an insufficient knowledge of his works and that

of his contemporaries. It is said of Saint Paul that his thoughts traveled faster than his stylus. Leeuwenhoek's description of his wonder world went so far as he, without artistic ability, could possibly depict. Compare his drawings of the insect eye with those of Swammerdam; his wood anatomy with that of Grew.

Being a true "bourgeois satisfait" he didn't feel his handicaps. He rather took a pride in the fact that he knew neither French, Latin, English nor German. Still, when we look in his works for his moments of true inspiration, we find them. His masterful account of the circulation in the tail of the eel, and his critical remarks on "generatio aequivoca" stand high above the level of his average work. His account of the body louse vies in distinctness of purpose and in whimsical description with the best passages in Fabre's "Souvenirs Entomologiques." But we have to wade through many a dreary page to reach places such as these.

Fortunately, a lack of imagination has its advantages. It does not disturb or urge the mind in several directions at once. It allows long and peaceful observation. It allows Leeuwenhoek to construct 527 microscopes of gold, silver and brass.

The estimate by one of his biographers that his portrait shows traits of both Cromwell and Spinoza is far from describing the actual Leeuwenhoek. No delicate disdain, but a rather coarse doggedness is depicted in his features. The characterization as given by one of his contemporaries fits well; kind, courteous, but illiterate.

Some are born great, some achieve greatness, some have greatness thrust upon them. Leeuwenhoek belongs to a fourth category. He was but a small fragment of a broken mirror, but he reflected the greatness of nature truthfully and directly. And he became great by reflection.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

THE BUILDING BLOCKS OF THE BODY

IT is fascinating to stand on the sidewalk and watch a building being put up by modern methods. The materials seem to appear by magic just when they are needed. The stones, cut and numbered, are delivered in proper order. The big steel girder arrives at the moment when its bed is prepared for it. Enough bricks are always on hand to keep the bricklayers busy and not many more. Sand, gravel and cement come along in the right quantities to mix for concrete, and little, if any, is left over at the end of the day. Doubtless, it is not all such smooth sailing as it seems. The boss may have his moments of worry over delayed delivery or the premature arrival of certain material. But the system must be well arranged, for on a narrow city lot there is little room for the storage of excess stuff, and the builder must live, so to speak, "from hand to mouth."

The building of our bodies has to be run on a schedule even more closely contrived than this, and physiologists are now beginning to comprehend its principles. Flesh and blood are largely composed of a sort of substances called "proteins," of which there are thousands of different kinds; enough to go around among all the animals and give each species a particular protein of its own. But these innumerable varieties are all made up of various combinations of a comparatively small number of simpler substances called the "amino acids" of which some twenty are now known.

How many of these several sorts are needed by any particular animal, such for instance as us, is yet undetermined. Probably a dozen, perhaps half a dozen, amino acids, if properly picked, would suffice. But our food must contain at least a little of every one of the set of amino acids that are required for the building of our bodies. If one of them is missing none of the other can altogether replace it. So, too, a typesetter must have some type in every box of his case. He can not get along without a few x's and g's, even though he may have plenty of a's and e's. But if he has as many x's and z's as he has a's and e's he can not make use of them.

So a little of a particular kind of protein may be very valuable, indeed essential. But double the amount is not twice as good, may not, indeed, be any better. Professor H. H. Mitchell, of the University of Illinois, found in the feeding of white rats that the biological value of protein from various foods ranked as follows: milk, 93.4; rice, 86.1; yeast, 85.5; oats, 78.5; corn, 72.; potatoes, 68.5. Doubling the amount of any one protein did not increase its nutritive value in proportion, but the addition of another kind of protein did increase in certain cases the value of both. For instance, rats fed on corn protein alone or on milk protein alone did not thrive as well as when the two were combined, although the total ration remained the same. Since rats have been the messmates of man from time immemorial they have acquired similar feeding habits to ours.

The lesson of this for us is that we should see that we have a varied as well as an adequate diet. There is nothing found in these investigations to

DR. ELIHU THOMSON

On whom the Kelvin Medal has been conferred. Dr. Thomson, who since 1880 has been a leader in the development of the Thomson-Houston and the General Electric Companies, has made important contributions to electrical engineering.

favor these food faddists who would have us live for life on a single kind of food such as peanuts or grapes. Even if we could know precisely what proteins our body needed at the moment and had the composition of the food down pat, we would have to have scales and slide-rule at every meal to figure it out. Better leave this complicated problem to be carried on by the unconscious calculation of our digestive apparatus, which will generally come out right if supplied with the proper kinds and amounts of building materials. If any one of them is lacking the rest can not be economically utilized.

Imagine the disgust of the construction boss if he should get several loads of sand and only one sack of cement. If it were a mistake in the kind of fuel delivered it would not be so bad. If there is a shortage of anthracite, one can use coke, or briquets, or even bituminous. But concrete has to be mixed in the proper proportions if it is to stand, so the boss having no storage space has to send away the excess sand unused.

So, too, in our body building. We need not be so particular about our fuel foods. There are many kinds of sugars, starches and fats, but they are more or less interchangeable. No one of them is indispensable. The question of quality does not matter so much in this case, nor quantity either, so long as there is enough of any of them. And if we eat too much of fats and carbohydrates, as many of us do, the surplus is disposed of with comparative ease or stored up in the body as fat. It is indeed a burden to travel with so much excess luggage as some of us do but we get along.

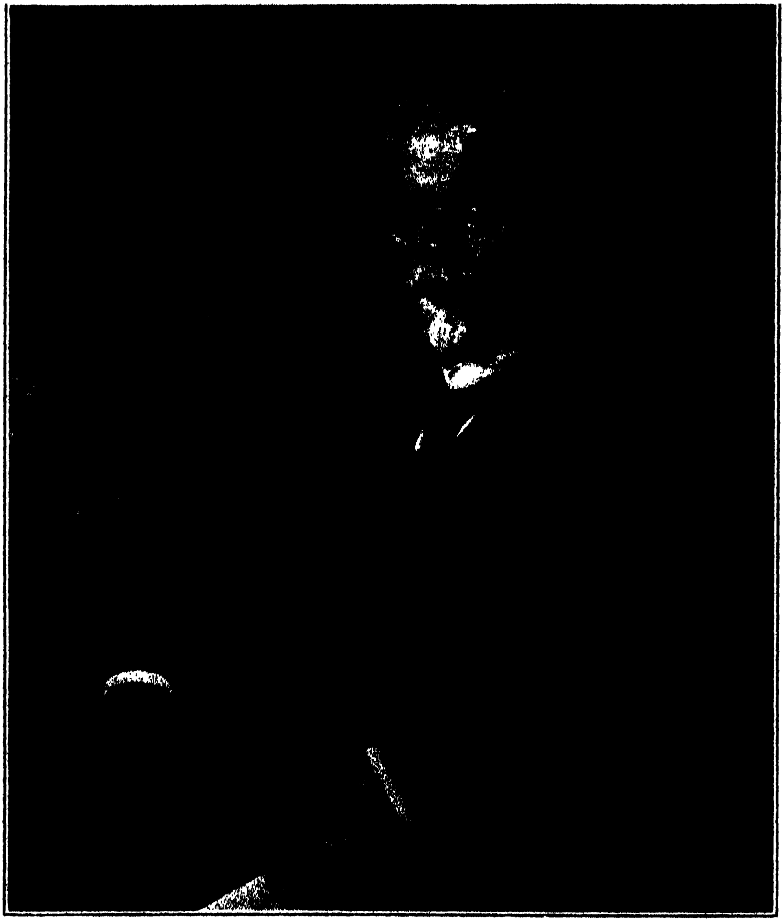
The proteins may also in part be burned up but their waste products are much more difficult to get rid of and are particularly obnoxious if allowed to accumulate in the body. So one of the delicate and difficult points in the problem of dietetics that we all have to solve every day is to see that we get proteins in sufficient assortment, quite enough of them, and yet not much too much.

TWO TYPES OF TEMPERAMENT

ARE you an extravert or an introvert? That is the way the question is put to-day. The phraseology is new for it was recently introduced by Jung. But the question is old, about two thousand years old, anyhow, for Galen made a similar effort to classify mankind by temperament. He distinguished between the "sanguine," who are quick, warm, impressionable and changeable, and the "phlegmatic," who are slow, quiet and persistent. When these two characteristic types are strongly marked they are called respectively "choleric" and "melancholic."

Another old classification of a similar sort is between "objective" and "subjective" or between "energetic" and "sentimental."

Professor William James devotes the first chapter of his book on "Pragmatism" to showing how our beliefs and reactions are unconsciously controlled by our temperamental bias and from this point of view he divides people into the "tough-minded" and the "tender-minded." The tough-minded, he says, are "empiricist (going by facts), sensationalistic, materialistic, pessimistic, irreligious, fatalistic, pluralistic and skeptical," while on the other hand, the tender-minded are "rationalistic (going by principles), intellectualistic, idealistic, optimistic, religious, free-willist, monistic and dogmatical." And he says you can tell them apart because "they have a low opinion of each other. The tough think of the tender



ROBERT ERNST EDUARD WIEDERSHEIM

In whose death Germany loses its most distinguished comparative anatomist.

as sentimentalists and soft-heads. The tender feel the tough to be unrefined, callous and brutal." The tough-minded of James corresponds roughly with the extravert of Jung and the tender-minded with the introverts.

Professor Wilhelm Ostwald, of Leipzig, in his study of great scientists divides them into the "romanticists" and the "classicists." The romanticist man of science is a good teacher; genial, versatile, expansive and popular; fond of conversation and quick to publish. He jumps at conclusions, sometimes making amazing discoveries by a sort of intuition and sometimes making sad mistakes from his impatience of detail. The romanticist gets paid in current coin; in the devotion of his disciples and in honors from his colleagues, sometimes in applause and wealth from the public.

The classicist on the contrary has to put up with deferred payment. His services to science often receive no adequate recognition till his death and not always then. He pursues a single line of thought persistently and systematically for years, often without outside aid or encouragement. His mind works mathematically and logically but he may be deficient in experimental and practical ability. He is reluctant to publish and apt to be a poor teacher. Among American scientists Benjamin Thompson, alias Count Rumford, was a typical romanticist and Willard Gibbs was a typical classicist.

Professor C. G. Seligman, president of the Royal Anthropological Institute, of London, in a recent address extended Jung's categories into wider fields. We can distinguish, he says, between extravert and introvert poetry and art. In painting, Rubens and Delacroix are extraverts and Poussin and Ingres are introverts. Japan as a whole is extravert while China and especially India are introvert. Savage races as a rule appear extravert as compared with civilized Europeans. Professor Seligman thinks that in any one people the two types appear in about equal numbers, though extraverts, being more responsive and better adapted to the world, give the impression of being in the majority.

These various attempts at splitting the human race into contrasting temperament do not agree closely as to dividing lines and distinguishing characteristics, yet there is obviously a certain similarity in the types recognized. Probably the physiologist will come in with a chemical classification based upon the hormones, which seem to be much like the long laughed at "humors" of past centuries. He may, for instance, use the activity of the thyroid gland as the criterion and call the extravert a "hyperthyroid" and the introvert a "hypothyroid." He may even attempt to alter temperaments to order by injection of some coal-tar compounds, as indeed he can do now to a considerable extent.

If you can not answer the question with which we began, so much the better for you, since it shows that you have a well balanced character. Though we may safely lean one way or the other, as doubtless we all do, yet we should not run to either extreme for that way madness lies. The extreme of the extravert is hysteria and the extreme of the introvert is dementia praecox.

THE LITTLEST LIFE

"How many angels can stand on the point of a pin?" was debated by the wise men of the Dark Ages. It was a good question for debate of the sort they delighted in because they never could find out and if they could it would have made no difference to anybody.

"How many microbes can stand on the point of a pin?" is the question that interests the wise men of modern times, not for the fun of discussion but because they can find out and because our lives depend upon their finding out.

For a single microbe may be more than a match for a man in single combat in spite of their disparity in size. Compared with this, the duel between David and Goliath was a fair fight on equal footing. The man, let us say, is five feet, ten inches tall. Against him we will pit a microbe of moderate size, say a bacillus measuring only a micron in height. A micron is a millionth of a meter, or, if you prefer, a twenty-five-thousandth of an inch. Such a microbe is not afraid to tackle a man, who is 1,750,000

times as tall and 5,000,000,000,000,000,000 times his fighting weight. Yet the microbe often succeeds in knocking him out.

For although the microbe has such odds against him on the start, they do not stay so. For the microbe grows faster than the man and is quicker at multiplication. The Asiatic cholera germ, for instance, doubles every fifteen minutes. If unlimited in space and food, its progeny would equal the mass of a man in the course of some fifteen hours. That is to say, a microbe that gets a lodgment in a man might eat him up in less than a day if the man were entirely edible and provided adequate accommodations.

To return to the point. I have just tried to measure the diameter of the point of a pin but my desk rule is not fine enough so I measured the head of it. It is not one of these new fashioned round-head pins but the common metal kind and its head is two millimeters across, that is, two thousand microns. Now the bacillus of typhoid fever is two microns long and one wide. So that a thousand of them could be end to end across the pinhead or two thousand lying side by side.

But these are big ones compared with some. It was formerly supposed that water could be made germ-free by forcing it through a filter of unglazed earthenware, but it is now known that fifty distinct diseases are caused by germs so small that they will pass through the pores of porcelain. Among these are such well-known human diseases as influenza, small pox, hydrophobia and measles, and a long list of plant diseases, especially those recognizable by mosaic discoloration of the leaves.

Most bacteria measure about a micron but the one that carries the flu infection, and is known as pneumosintes, may be only a tenth of that length. The chicken plague and the mosaic diseases of tobacco are carried by something still smaller, say a fortieth of a micron.

Now when the biologist gets down as fine as this he comes into conflict with the chemist. For a single molecule of hemaglobin, the red coloring matter of the blood, is bigger than one of these creatures—if they are creatures. If they are not, how is it that they can grow and multiply and carry their specific characteristics over from one animal or plant to another? But if they are living organisms they must be largely composed of protein and the protein molecule is so large that the chemist can only allow the biologist a few hundred or at most a few thousand molecules out of which to construct the necessarily somewhat complicated machinery of these virulent bodies.

But in spite of the criticism of the chemist the biologist continues to discover minuter bodies which possess some of the functions of life. Bacteria are found to be devoured by something that d'Herelle of the Pasteur Institute calls "bacteria eaters," or if you insist upon the Greek of it, "bacteriophages." These also are filter-passers and must be much smaller than the bacteria on which they prey, but whether they belong to the realm of chemistry of biology is still in dispute. Possibly the question may be settled in the end by finding that there is no definite dividing line between the two realms.

THE SCIENTIFIC MONTHLY

JUNE, 1924

THE DEVELOPMENT OF EGG-FRAGMENTS[1]

By Professor T. H. MORGAN

COLUMBIA UNIVERSITY

THE study of isolated blastomeres has shown that they continue to divide as though still in contact with their fellows, and that whole embryos of half size develop in some cases but incomplete embryos in others. These results demonstrate that the conditions determining the form of the later cleavage are already present after the completion of the first division of the egg. How much before this time the future course of events has been determined, so far at least as the cleavage is concerned, has been studied by cutting the egg into fragments, both before and after the entrance of the spermatozoon.

In those eggs in which the large egg-nucleus is present when the egg is removed from the female and in which the extrusion of the polar bodies takes place after its removal, there is given an opportunity of finding out whether, during this period, alterations are taking place that condition the cleavage pattern. In these same eggs, as well as in those in which the polar bodies have been already extruded when they are obtained, there is an opportunity of finding out how far the cleavage pattern is determined after the entrance of the spermatozoon into the egg. The study of fragments has also shown to what extent the cleavage pattern is foreshadowed as the time approaches when the first division is about to take place.

The earliest observations on egg fragments were made on pieces of the sea urchin's eggs (Hertwig ('87) Driesch, ('96) Morgan ('94) Delage ('99) Boveri ('89, '95, '14, '18)). The pieces were obtained in most cases by violently shaking the eggs until they were fragmented. This method is not well suited to bring out the essential relations involved, both because the situation of the frag-

[1] Chapters from Experimental Embryology. VI.

ment in the egg from which it came is not known, and because in the sea urchin the observations are limited to the period after the polar bodies have been formed. More significant results have come from the study of egg-fragments of Cerebratulus (Wilson ('03), Zeleny ('04), Yatsu ('04)); of Dentalium (Delage ('99) and Wilson ('04)); and of Beroë (Driesch and Morgan ('95), Yatsu ('10, '12), Fischel ('98, '03)).

The Development of Fragments of the Egg of the Nemertean Cerebratulus

The egg of Cerebratulus when taken from the worm at the height of the breeding season contains a large egg nucleus (Fig.

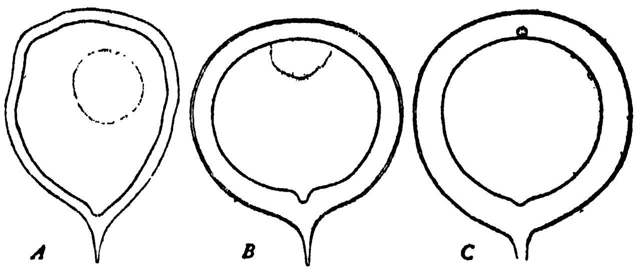


Fig. 1

1 A). The egg is slightly oval in shape and there is an extension of its protoplasm at the antipole that is the remnant of the stalk that attached the egg to the wall of the ovary. With a fine, sharp

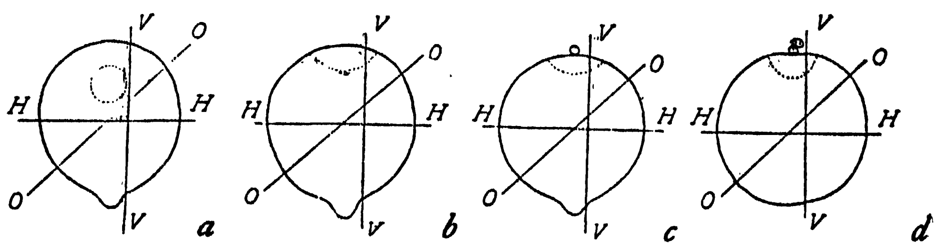


Fig. 2

scalpel the egg may be cut in two in any desired plane (Fig. 2, a–d). Owing to its viscosity both fragments remain intact, and soon round up into a spherical or nearly spherical shape. One fragment contains the egg-nucleus, the other is without a nucleus. The nucleus of the former proceeds to resolve itself into the first polar spindle. When the metaphase stage is reached further progress stops until a spermatozoon enters the fragment. In this respect the nucleated fragment behaves in the same way as an intact egg. The subsequent history of the fragment may be briefly told. It segments

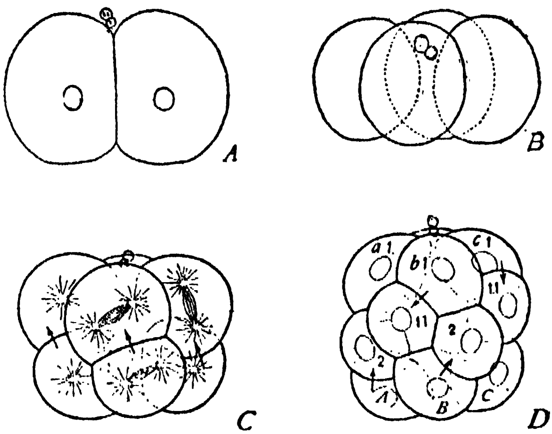


FIG. 3

(Fig. 4) in the same cleavage pattern as does the whole egg (Fig. 3). The blastomeres have the same relative size relations as have those of the normal egg or in other words the cleavage is proportional. At the third division of the normal egg (Fig. 3, C) the spiral type of cleavage appears, and the fragments also divide at this time in a right-handed spiral (Fig. 4, C, D). This result is the same regardless of the region of the egg from which the fragment came. In some cases, as shown in Fig. 4, C, the cut was "horizontal" and in other cases "vertical" (Fig. 4, A) and in others "oblique"; nevertheless, the cleavage pattern was the same in all cases. This result shows that prior to the breaking down of the egg-nucleus there were no regional differences present in the egg that determine the form of its cleavage. From these fragments, if not very small, normal embryos develop that are miniature copies of the whole embryo (Fig. 5, B and D).

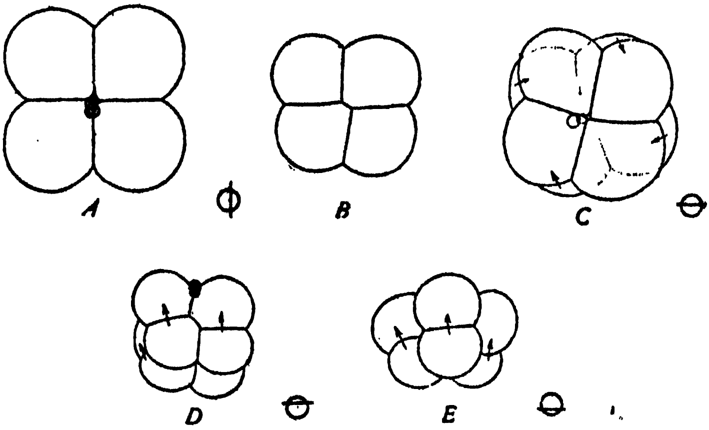


FIG. 4

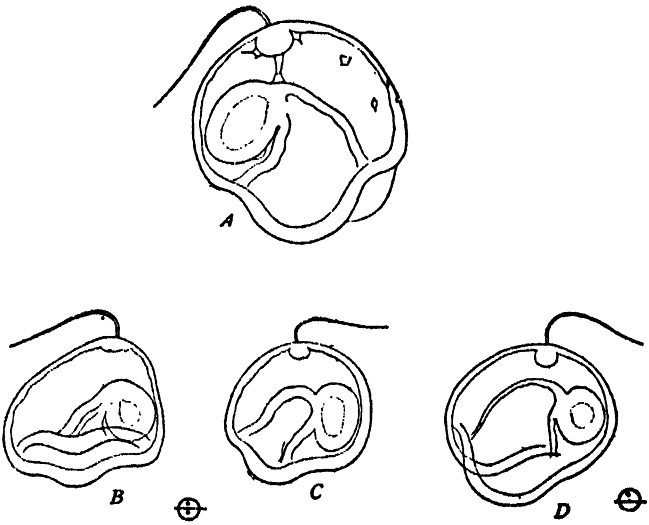


FIG. 5

The other piece of the egg—the one without a nucleus—can also be fertilized by a spermatozoon. It, too, shows in the normal cleavage pattern (Fig. 4, B, E). Since its nucleus is derived solely from the head of the spermatozoon the fragment contains only half the full number of chromosomes (haploid). This condition, however, does not affect its mode of cleavage. It is true that the haploid nature of the fragment has not been proven in this case, but since its cleavage is said to be synchronous with that of the other piece, there can be little doubt of the interpretation. This haploid fragment also forms a normal embryo—if not too small—irrespective of the way in which the fragment was removed (Fig. 5, C).

If, instead of fertilizing the fragments as soon as obtained, the operation is delayed until the first polar spindle in the nucleated fragment has developed, the results are the same as before, from which it follows that during this interval no changes have taken place that affect the cleavage pattern.

In order to study the later phases it is necessary to first fertilize the egg and wait until the first polar body has been given off and then cut the egg. The results from the nucleated piece, if it also contains the sperm head, are the same as before, and this is also true if the cut is not made until the second polar body has been extruded.

THE DEVELOPMENT OF FRAGMENTS OF THE EGG OF THE MOLLUSC DENTALIUM

Delage ('99) cut 18 unfertilized eggs of Dentalium into two pieces, and in six cases both fragments segmented. The first

cleavage was only "rarely" into two equal parts; more usually the fragment divided at once into four parts. It is probable that these fragments are polyspermic or that Delage mistook the yolk lobe for a blastomere.

Unfortunately, no information is given as to the details of the cleavage or as to the type of cleavage of the nucleated and non-nucleated fragments. Normal as well as abnormal embryos were obtained from both kinds of fragments. Information that is lacking in Delage's account is supplied by the later work of Wilson ('04) and the following statements and illustrations are taken from his paper. The eggs were cut in two with a scalpel, and the fragments were then fertilized. Both pieces often segmented. In the figures (7–9) the position of the cut is indicated by the smaller circle near each picture of the cleavage, and the piece that divided is indicated by a black dot. The upper part of each of these small circles indicates the pole. The egg nucleus after the extension of the polar bodies lies in this region. The polar bodies are given off from the polar fragment after the operation. Their presence makes it possible to determine which of the two fragments contains the egg nucleus as well as its regional relations. The normal cleavage of Dentalium is shown in Fig. 6. The presence of the yolk lobe that first appears at the time of the first cleavage and which remains attached to one of the blastomeres (D) makes it possible to follow in detail several interesting features in the cleavage of the fragments and to compare them with the cleavage of the whole egg.

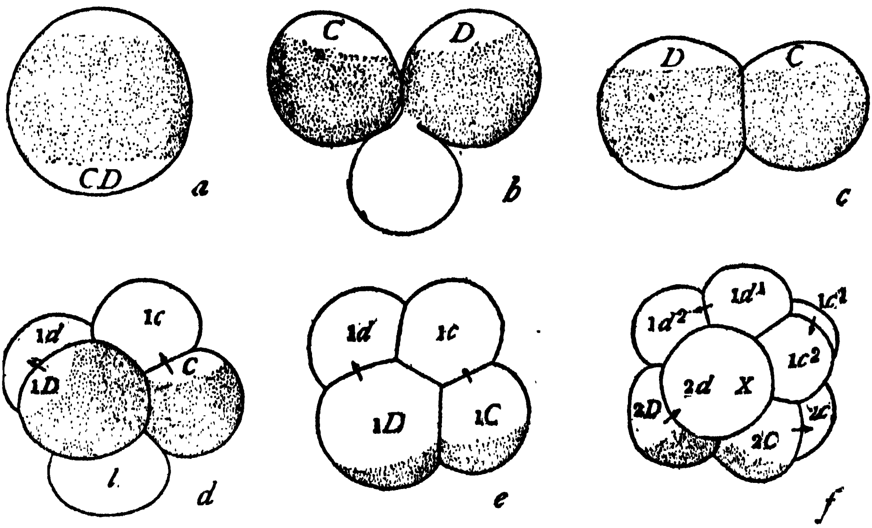


Fig. 6

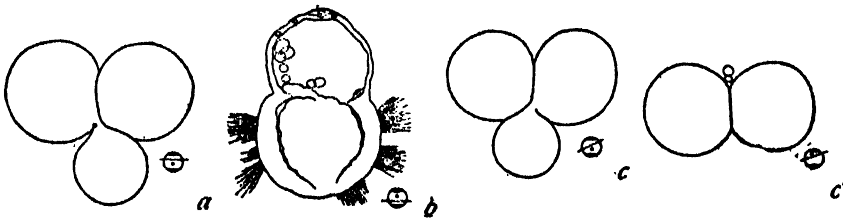


FIG. 7

When the unfertilized egg is cut in two nearly equal parts in a horizontal plane (Fig. 7, c′), and then fertilized, the polar nucleated fragment divides into equal parts as does the normal egg, except that no basal lobe appears. The second cleavage is again equal. The succeeding cleavages are spiral, quartets of micromeres being formed by alternating dexiotropic and leiotropic divisions. Many of the embryos fail to develop, but others develop into actively swimming trochophores (Fig. 7, b) that are never quite normal. These larvae sometimes agree precisely with those derived from whole eggs from which the basal lobe has been removed. These will be described later. In a few cases an apical organ is present. When the upper fragment is larger than the lower one, it may form a small basal lobe.

The lower (basal or antipolar) fragment (Fig. 7, a) may segment "in every detail like an entire egg of diminished size, forming the polar lobe in normal fashion, and may give rise to a dwarf larva nearly or quite normal in form and possessing an apical organ" (Wilson). Moreover, while there is much variability in the size of the polar lobe, it is often of exactly proportionate size, even when the section has passed above the limits of the white antipolar field. The form of the cleavage is, within limits, independent of the size of the piece, that is, both large and small fragments (¼ full size) may segment as wholes (Fig. 7, a–c). Many of the embryos perish, and of those that live many are abnormal, but occasionally a dwarf embryo is produced that is a normal trochophore except in size.

When the egg is cut in two, parallel to the primary axis, *i.e.*, vertically, and the fragments fertilized, both halves may develop (one diploid, the other haploid), both produce a lobe, since the antipolar white field was cut in two. A case of this kind is shown in Fig. 8, a, a′, b, b′. The yolk lobe is sometimes relatively too small, but in other cases it may be of proportionate size. Some of the larvae from such a vertical section approach in form the normal trochophore and without doubt normal embryos can be obtained from such fragments.

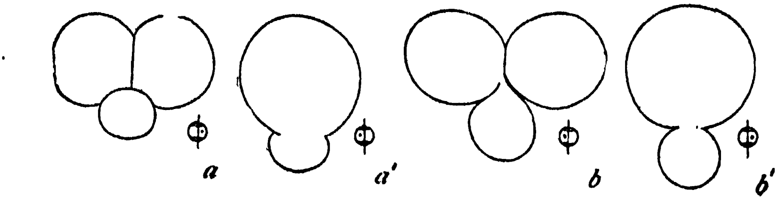


FIG. 8

The preceding statements apply to eggs cut before fertilization and subsequently fertilized. Eggs were also operated on after the first or second polar bodies had been given off, therefore after fertilization. Only the fragment with the egg nucleus segments. If cut horizontally, the polar nucleated piece segments as a whole egg, but without the basal lobe. The larva is normal. The behavior of the basal non-nucleated piece is most remarkable. "It forms three times in succession a polar lobe from the white area at the same time that the nucleated half is dividing." This change is comparable to that shown by the lobe itself when cut off from a whole egg. It shows periods of activity that are synchronous with the cleavage of the egg from which it was removed. The lobe may even form a smaller lobe that simulates the lobe of the normal egg.

Normal entire eggs from which the lobe is cut off continue to segment in the normal fashion except that no lobe reappears, and the D quadrant is no larger than the others. Such embryos gastrulate and give rise to swimming larvae, but the post-trochal region is absent and they show no trace of an apical organ. The absence of the apical organ and of other organs normally present in this region is not due to the decreased size, since still smaller embryos from basal fragments produce these parts. Wilson concludes that the results are due to some materials present in the lobe itself that are essential for the development of even the apical organ.

The Development of Fragments of the Egg of the Ctenophor, Beroë

It was shown by Driesch and Morgan ('95) that fragments of the unsegmented eggs of Beroë segment sometimes as wholes and sometimes as parts of wholes. They surmised that this difference

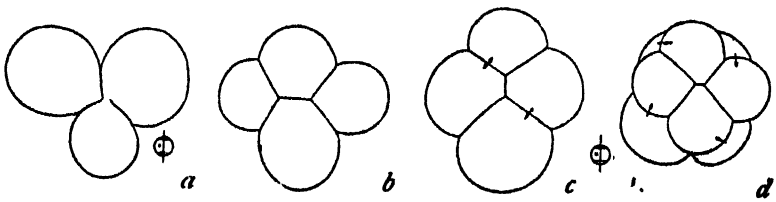


FIG. 9

might depend on whether the cut was symmetrical with respect to the pole or on one side; and the later experiments of Yatsu have shown that this is true, if the cut is made when the first cleavage is about to take place, but for oblique cuts the differences in the type of cleavage depend on the time at which the operation is performed. The cleavage of fragments of the egg of Beroë was later studied more in detail by Yatsu ('11, '12), and to a limited extent by Fischel ('98, '03) and Ziegler ('98).

Yatsu cut unfertilized eggs soon after being laid (the plane of the section was not determined) and, in the two cases examined, the cleavage was normal. After the two polar bodies had been extruded other eggs were cut in various planes. Three eggs were cut vertically, *i.e.*, parallel to the egg axes. Normal cleavage followed, although the middle and end cells on the cut side were somewhat smaller than their vis-a-vis, but the micromeres were the same in all (Fig. 10, a). Six eggs were cut obliquely (Fig. 10, b) with results

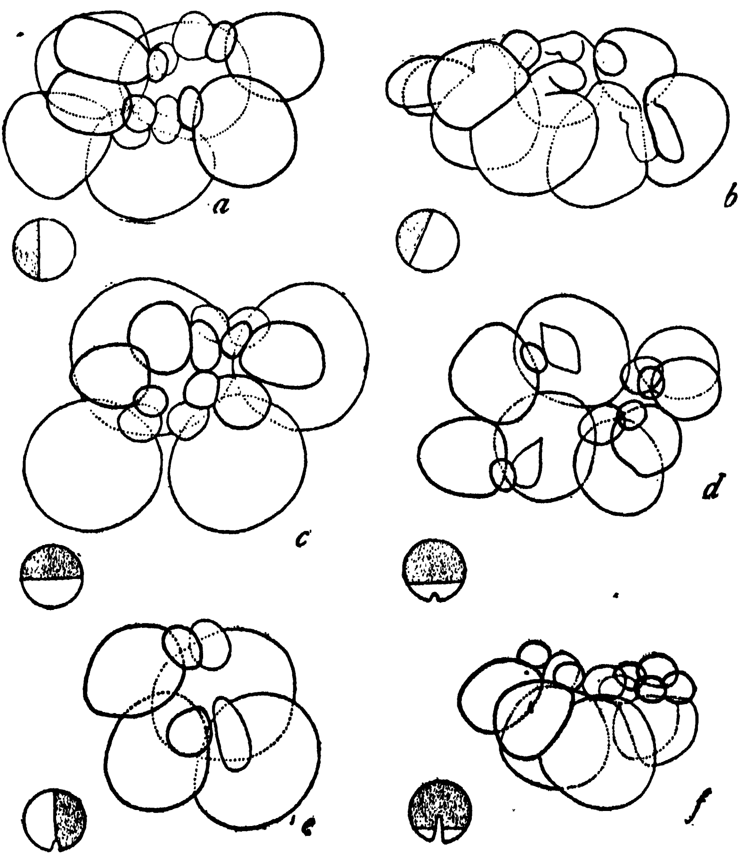


FIG 10

as before. One egg was cut horizontally (Fig. 10, c). The end cells were small, but the micromeres were almost as large as in the normal egg.

At the beginning of the first cleavage three eggs about to divide were cut horizontally (Fig. 10, d). The small polar fragment divided normally. Seven eggs were split in two in the plane of cleavage (Fig. 10, e). The fragment cleaved as a half. Further experiments of the same sort—more especially after the first cleavage had progressed some distance—were undertaken by Yatsu to see how far the subsequent divisions give "proportionate" cleavage patterns. Most of the sections were horizontal, and only the nucleated fragment segmented (Fig. 10, f). Even when the polar end was cut off after the cleavage head had passed beyond the plane of section (Fig. 11, b, e, d), the fragment gave a proportionate, whole cleavage. This is all the more surprising when it is recalled that if the dividing egg is cut in two in the plane of division each half cleaves as a half. It is evident, however, that in the latter case each half is more like the normal half blastomere and the mitotic figure is the same and the material is the same as that of the half blastomere; while in the former case the small polar fragment contains the two nuclei with their surrounding materials (although much reduced in volume) and these are symmetrically placed around the pole. If the size of the mitotic spindle is dependent on the cell content, and if the cleavage is determined by the spindle rather than by the material of the cytoplasm, one can under-

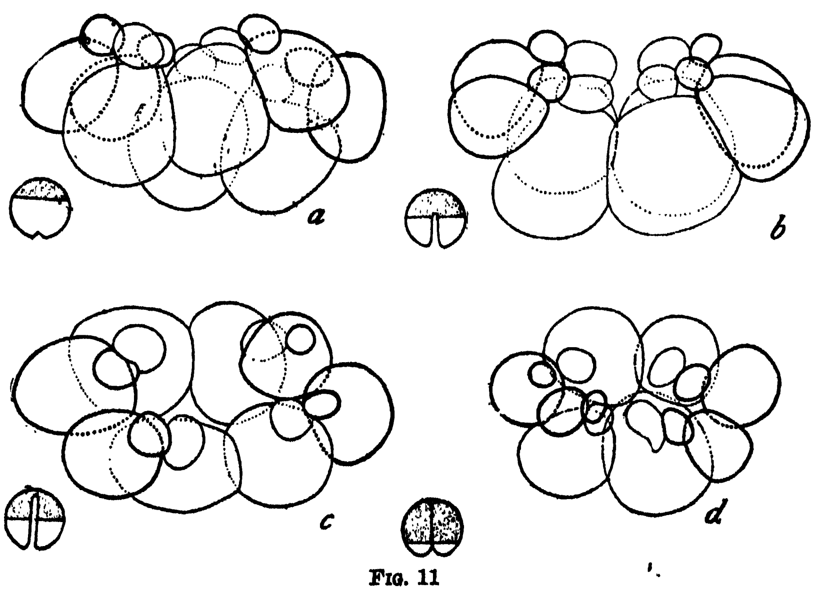


FIG. 11

stand to some extent, at least, why the cleavage of these polar fragments is proportional.

There is another important fact shown by these experiments of Yatsu. If the section is made when the first cleavage is just beginning, the nucleated (polar) end contains a great part of the ectoplasm that at this time has moved into the polar region, yet the micromeres are no larger than in the case when the section is made towards the end of the first cleavage at which time much of the ectoplasm has left the polar region and moved into the antipolar field. Evidently, the amount of ectoplasm is not in itself the factor that determines the size of the micromeres, although in the normal egg they appear to be largely composed of this material.

The Development of Fragments of the Eggs of Sea Urchins

The experiments with fragments of the sea urchin's eggs were the first of the kind to draw general attention to the importance of this method of studying the changes in the egg prior to its cleavage. The work of Boveri ('89, '95, '14, '18), Morgan ('94, '95), Driesch ('96), Delage ('99) on the sea urchin's egg showed that the nucleated fragments of this egg may develop into whole embryos of small size. It was also found that even the non-nucleated fragments might also divide if entered by a spermatozoon, and it was supposed that they also might produce small embryos.

If the eggs of the sea urchin are shaken violently in a small tube before fertilization they may be broken up into fragments of various sizes; some of the fragments contain the egg-nucleus, others are without a nucleus. The fragmentation is more easily brought about immediately after fertilization. We do not know explicitly how each of the two kinds of fragments behaves, but it is known that the fragments that contain both the egg-nucleus and the sperm develop, while those that contain only the sperm may segment and the larger ones at least are supposed to gastrulate and even produce plutei.

The cleavage of egg-fragments of sea urchin's eggs, obtained before fertilization, has been studied by Morgan ('93), Driesch ('96) and Delage ('99). Morgan described the cleavage as very irregular. The pattern was not like that of the whole egg. Driesch examined eggs of two sorts. One lot of eggs was shaken an hour after fertilization, hence just before its first cleavage is expected. Seven types of cleavage patterns were found; all "partial" or irregular. Some of the larger pieces especially showed at times a close approach to half cleavage. Driesch ascribes the different types observed to the fragments coming from different regions of the egg, and since the eggs were fragmented just before the first

cleavage is due this seems a probable explanation in the light of evidence from other sources. Driesch also studied the cleavage of eggs that were broken into fragments before fertilization. He found that these fragments also showed great variability in their cleavage pattern. The same types that he had obtained from fragmentation of later stages (described above) reappeared here also. In a few cases, especially in the larger fragments, normal cleavage was observed. He concluded, nevertheless, that partial and not whole cleavage is the rule and inferred that the cleavage pattern is predetermined in the egg.

Delage cut each egg into two parts—a method that is better suited to give an answer to the question involved. The fragments were then fertilized. In six cases both fragments divided. Delage states that "the cleavage takes place as in the normal egg," but no details are given and, judging from the result he records for fragments of other kind of eggs, it seems probable that Delage did not follow the cleavage in sufficient detail to answer the question as to whether the characteristic features of the cleavage were those of the whole egg.

From the foregoing evidence it is uncertain whether fragments of the sea urchin's egg obtained after the polar bodies have been extruded, but before fertilization, segment as parts or as wholes. It is quite possible that the rough treatment employed when the eggs are broken by shaking injures them or disturbs their structure to such an extent that the irregularities observed in the cleavage are due to disturbance of the structure rather than that they represent partial cleavage. The method of cutting the egg is undoubtedly better and might be expected to give the information called for, but Delage's statement is too vague to be satisfactory.

That the cleavage of fragments obtained just before cleavage should be partial is, as I have said, very probable and is due to changes that have begun in anticipation of the normal cleavage. On the other hand, if the fragments from earlier stages had segmented as wholes we should expect this to have been seen at once by the several observers on the cleavage of such fragments. In the absence of such observations, I am inclined to believe, with the reservations spoken of above, that the cleavage pattern of these fragments is partial and that it is due to changes that have taken place after the polar bodies were extruded.

Fertilization of Non-nucleated Fragments of the Egg of One Species of Sea Urchins by Sperm of Another Species

Boveri ('89, '95, '14, '18) carried out the ingenious experiment of fertilizing the non-nucleated fragments of an egg of one species of sea urchin by sperm of another species in order to discover

whether the characters of the larva are determined by the protoplasm or by the nucleus or by both.

It is true that this question is to-day definitely settled by Mendelian crosses where single differences are involved, and unless there is something unknown and peculiar where species are concerned there is every expectation that, given sufficient time, the nucleus will determine the character of the structures produced by the cytoplasm, but when, in 1889, Boveri first made his experiment all this was not known or at least not appreciated. Boveri himself held later ('06) that "fundamental characteristics" of the organism are determined by the cytoplasm, while the smaller details in which species differ from each other are regulated by chromosomal activities. But this point is scarcely involved in the experiment in question, since the "fundamental" structures are the same in both species of sea urchin used for the experiments. The real question to-day is only whether the influences under which the cytoplasm of the egg has been produced will affect the character of a pluteus that contains a nucleus of another species. Boveri's experiments were made with the eggs of Sphaerechinus fertilized by the sperm of Echinus. The normal pluteus of Echinus is shown in figure 12, a and d in side and in front view; that of Sphaerechinus in figure 12 c and f; and that of the hybrid in figure 12 b and e. A hybrid pluteus of "pure" Echinus type from an egg fragment of Sphaerechinus fertilized by a spermatozoon of Echinus is shown in figure 12 c, and two views of another similar hybrid are shown in figure 13 a and b. Most of the small plutei that developed from cross-fertilized fragments were intermediate in form and in the structure of their skeleton, but a few were found that were like those in figure 13, that were purely paternal, and these Boveri concluded were derived from the non-nucleated egg fragments of Sphaerechinus that had been fertilized by the sperm of Echinus. He concluded from this evidence that the nucleus determines the character of the pluteus, even when the cytoplasm belongs to another species, in so far as the two species in question differ from each other.

The validity of Boveri's evidence was questioned by Seeliger ('95, '96) and by Morgan ('95) on the grounds that the full-sized hybrid plutei derived from this cross sometimes produced larvae whose skeletons are purely paternal. Boveri's general conclusion was not challenged, but the evidence for it was questioned. In fact, while it seems highly probable that paternal larvae might sometimes be produced in this way depending in the main on how far the earlier influence on the cytoplasm carried over to the pluteus stage, yet the evidence to prove this was inadequate under the

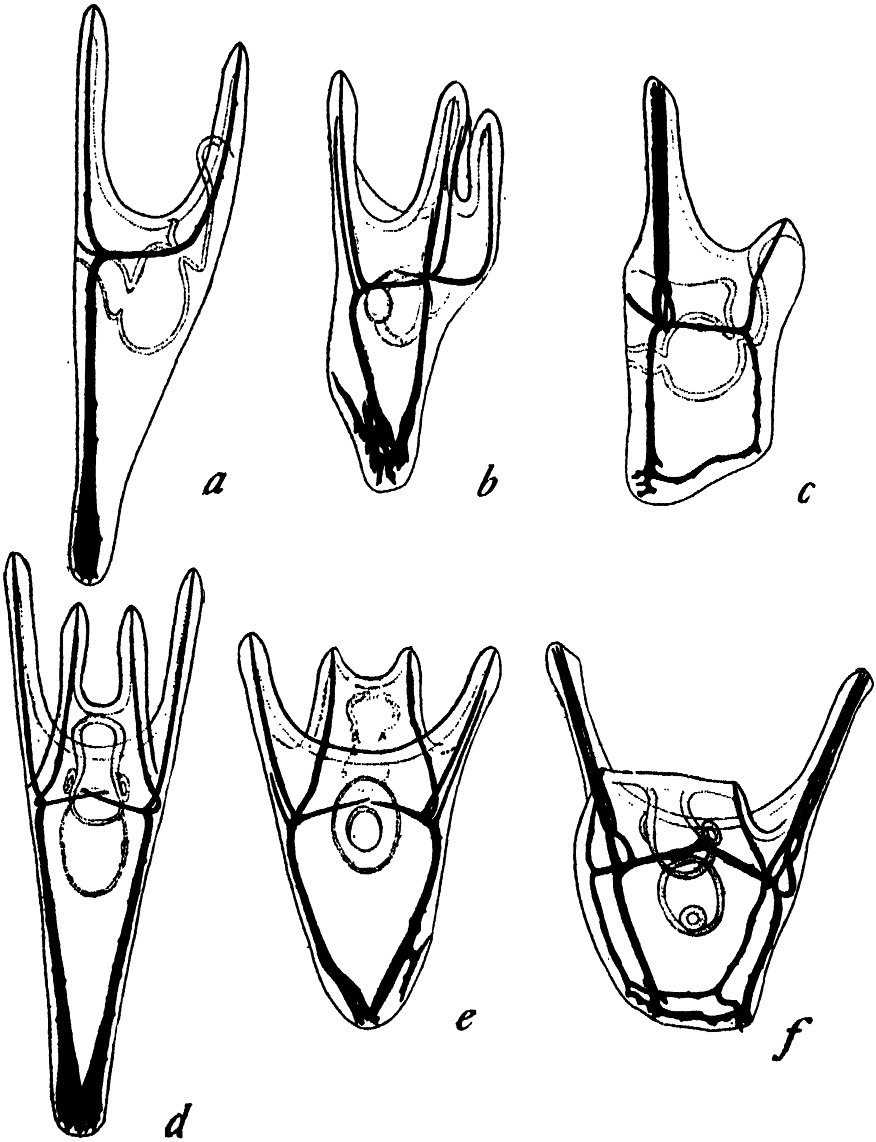


FIG. 12

conditions of the experiment. Boveri was loth, at first, to recognize the value of the evidence advanced by Seeliger and Morgan, but in his last paper is more inclined to give credence to it. In fact, he later concluded that the hybrid plutei with paternal skeleton had indeed come from nucleated fragments.

Boveri continued for several years to search for convincing evidence to settle this question. He tried out especially the method

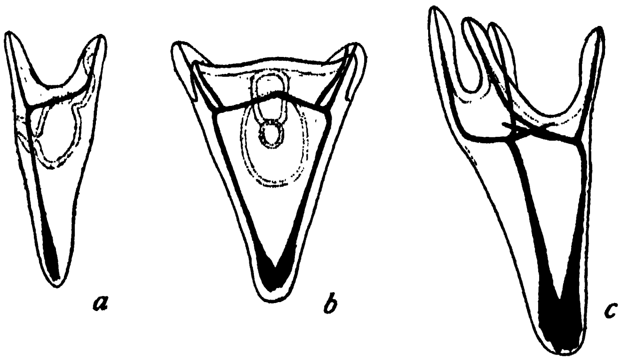


FIG. 13

of isolating fragments of eggs in which no nucleus could be seen. This work is extremely laborious and disheartening, since even when embryos are obtained few of them reach the pluteus stage. It was not until the winter of 1911–12 and again in 1914 that he finally obtained the evidence he sought. The new results were published in 1918 a year after his death. He had found that none of the hybrid larvae from non-nucleated fragments develop beyond the late blastula or early gastrula stage; hence do not furnish the evidence required.

In the course of this work Boveri went so thoroughly into all sides of the question involved that his procedure will stand as a model of the highest type of embryological inquiry. It showed throughout a freedom from bias, a critical thoroughness of procedure and a resourcefulness of methods that call for the highest admiration. The clue to the final solution Boveri found in a more detailed study of the fragments of the Sphaerechinus eggs that were apparently without nuclei. Most of these fragments produced sickly blastulae that went no further, or at most formed the beginning of the gastrula stage, but in addition there were a few well-formed plutei. These were not all of paternal form, but on the contrary most of them were clearly intermediate in their skeletal form as in the case when an entire egg of Sphaerechinus is fertilized by a sperm of Echinus. These plutei were killed and stained, and it was found that their nuclei were as large as those of a hybrid from an entire egg. In other words, they were diploid. It seemed probable, therefore, that the supposedly non-nucleated pieces had really contained the normal number of chromosomes. Delage, in fact, had noted earlier that an apparently non-nucleated fragment might contain the constituents of the nucleus, if the nuclear wall had broken down as a result of the shaking. Boveri also found later that when the eggs of Echinocardium are shaken the nucleus disappears from view in many eggs, but when killed and

stained a deep mass of chromosomes could be detected, as Morgan had earlier shown for starfish eggs. This mass resolves itself into its constituent chromosomes when the egg is fertilized, and combining with the sperm nucleus forms a normal segmentation nucleus. Baltzer ('10) had in the meanwhile repeated the experiments of isolating supposedly non-nucleated fragments, crossing them with sperm of another species, and had found that all but two died as blastulae. The two that became plutei when stained were found to contain full-sized (diploid) nuclei, and must, therefore, have contained originally chromosomes derived from the egg.

Boveri ('18) repeated his isolation experiments once more. Two hundred egg fragments apparently without nuclei were isolated. From them eleven well-developed plutei were obtained. Eight of them had large nuclei, and the fragments from which they came must have had invisible maternal chromosomes when isolated. Of the three remaining plutei two had both larger and smaller nuclei. They were, therefore, of doubtful origin and may have come from partially fertilized egg-fragments, or from eggs whose nuclei had been in the form of isolated vesicles as rarely occurs. The third pluteus having small nuclei showed probable indications of hybrid origin in its skeleton and is, therefore, also of doubtful value as evidence.

Finally, Boveri returned once more to mass cultures of egg-fragments. Eggs of Sphaerechinus were broken up and fertilized in some cases with Echinus sperm, in other cases with Strongylocentrotus sperm. At intervals large numbers of fragments were preserved. Judged by the standard of nuclear size, he found that both the fertilized non-nucleated and nucleated fragments develop at first at the same rate. But when the blastula stage is finished the small nucleated fragments cease to develop, while the others go ahead to form plutei. The oldest of the small-nucleated embryos stopped developing during the gastrula stage—only two showed traces of the triradiate spicules. This evidence, added to the rest, shows that the non-nucleated fragments, fertilized by the sperm of the other species, are unable to reach the pluteus stage. It seems probable that the foreign nucleus alone is unable to impress its characteristics on the cytoplasm that has developed under the influence of its own nucleus. But why it fails to do so is not at all evident in the light of the characters of the hybrid pluteus from whole eggs that are intermediate. Here the paternal chromosomes even in the presence of the maternal chromosomes are able to affect the character of the hybrid pluteus.

One further source of evidence must be added before attempting to interpret these results. Non-nucleated fragments, of Sphaere-

chinus fertilized by their own sperm are able to produce plutei that have, of course, the characteristics of the species. Furthermore, Boveri found ('12) that the non-nucleated fragments of Sphaerechinus eggs fertilized by the sperm of a closely similar species, Strongylocentrotus, also produced plutei. The plutei of these two species are so similar that it is not possible to determine whether the hybrid monospermic (small-nucleated) plutei are more paternal than the hybrid pluteus. Nevertheless, the result shows that the nucleus of one species and the cytoplasm of another species may combine to form a pluteus. Why, then, does not the more extreme combination develop as far? We can only conjecture that it is because of some secondary failure of this combination to reach this stage. It does not seem to be due to any very "fundamental" conflict between the nucleus and the cytoplasm.

In the light of his own results Boveri considers adversely the evidence that Godlewski has furnished relating to the fertilization of supposedly non-nucleated fragments of the eggs of the sea urchin, Echinus, by the sperm of the crinoid, Antedon. Godlewski ('06) found that, while most such fragments died after fertilization in early stages, four reached the gastrula stage, and that these were of purely maternal type. This means that the foreign sperm had

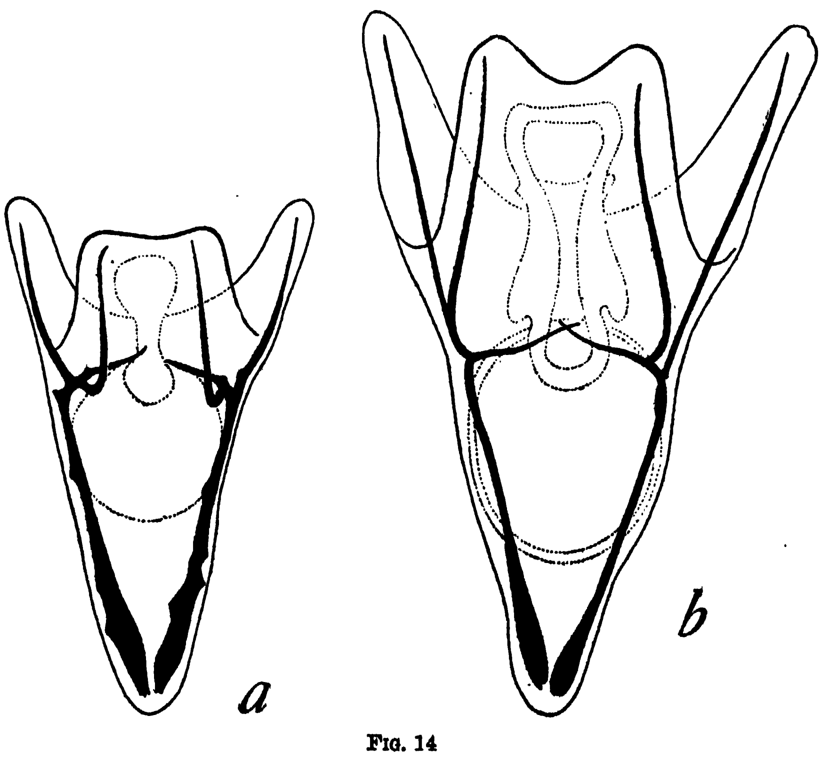


FIG. 14

failed to impress on the protoplasm the particular gastrulation type of its species. The gastrula stages are so different in the sea urchin and crinoid that it ought to be evident whether the gastrula followed one or the other method of development.

Since Godlewski made no measurements of the nuclear size, Boveri believes that there can be no doubt but that these supposedly haploid gastrulae came from fragments whose chromosomes were present even though invisible in the living fragment. The probability of the correctness of Boveri's diagnosis is very great in the light of the other evidence furnished by Godlewski and by Baltzer, namely, that the hybrids from whole eggs (Fig. 14, b) are also strictly maternal.

The Development of a Part of the Egg of the Salamander, Triton

Spemann ('19) obtained an embryo that developed from a part of a triton's egg that contained one sperm. His method was as follows: A hair was tied around the egg immediately after fertilization and tightened until the egg was constricted into two parts of unequal size. More than one sperm enters the egg of triton as a rule. The point of penetration is often marked by a light fleck on the surface. The location of the polar spindle of the egg is also indicated by a whitish area at the pole. In one case where one portion was smaller than the other (Fig. 15), the larger portion contained the polar bodies and presumably the egg nucleus and one or more spermatozoa. The smaller portion contained a single sperm as indicated by its point of penetration (in the left hand portion of Fig. 15). Both portions began to divide and were separated later. Each produced an embryo. A repetition of the experiment gave a few other embryos. Those from the mono-

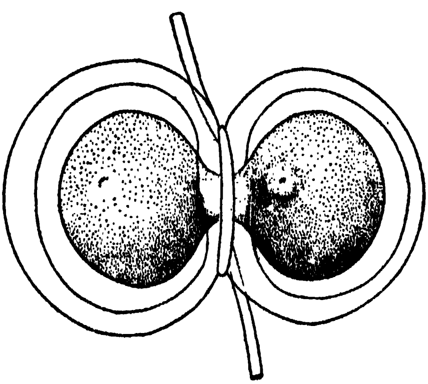


Fig. 15

spermic portion often produced embryos, but these did not live beyond the earlier stages.

Baltzer ('22) has repeated this experiment and obtained in one instance a dwarf larva that developed as far as metamorphosis when it died. It was less active than a normal larva and moved about slowly. An examination of its nuclei showed that they had only half the volume of those of a normal, or diploid triton. There is no doubt that Baltzer's larva was haploid.

In this connection the earlier results of Oscar and Gunther Hertwig ('12) must be mentioned. By treating the egg of the frog with radium they succeeded in injuring the polar spindle, so that the egg-nucleus was destroyed. When such eggs are fertilized some of them develop with haploid nuclei, but the embryos die after several days or weeks. Their cells contain nuclei that have only half the volume of those of normal embryos. Paula Hertwig ('20) has fertilized frogs' eggs that had first been denucleated by radium, with sperm of the toad. Some of these eggs developed as haploid larva, others, by delaying the first cleavage, diploid, but unfortunately neither kind went far enough to show whether they were purely paternal in their characters.

Conclusions

The study of egg-fragments has brought out certain facts of general interest to embryologists. The results have shown, for instance, that the mere entrance of the spermatozoon into the egg does not suffice to start development, for, if the egg be then cut into two pieces in such a way that the sperm-nucleus is present in one fragment and the egg-nucleus in the other, the former develops but not the latter. It follows that those theories of fertilization that have been proposed which terminate with the entrance of the sperm into the egg are entirely inadequate to explain the process of fertilization.

The study of the cleavage of fragments indicates that its pattern is not foreshadowed or predelineated in the protoplasm, but that the form of cleavage appears *pari passu* with the development of the mitotic figure in the piece. The surface conditions of the egg do not appear to condition either the type of the cleavage or the relative sizes of the cells. On the other hand the position and size of the spindles appear to determine the character of the cleavage about to take place. In fact, the proportionate type of the cleavage shown by fragments may be little more than an outward expression of the size of the spindle which in turn is an expression of the material available for its formation. If this inference is correct it calls for a further examination of the phenomenon of gelation (or

hardening) of the colloidal material of the egg that appears to be an important part of the physical expression of the mitotic phenomenon. How the alternating changes from gel to sol affect the kind of spindles that develop as cleavage follows cleavage we do not know. We must invite the assistance of the physical chemist to help us forward.

The development of embryos that contain the half number of chromosomes has been definitely established by the study of fragments that contain the sperm-nucleus, and there can be little doubt also but that a fragment containing the egg-nucleus alone, if it could be incited to divide, would also give rise to a haploid embryo. The development of whole eggs brought about by reagents that start its development prove that one set of chromosomes suffices to produce an embryo. Nevertheless, the delicacy of these haploid embryos is known both from the results of experimental embryology and from genetics. The failure of non-nucleated fragments of the egg of Sphaerechinus to develop into a pluteus, under the influence of the sperm of Echinus, does not mean that such an occurrence in general is impossible. Boveri has shown, in fact, that a haploid hybrid may be formed in another combination. The question that this experiment was intended to answer has, however, been answered by modern genetics. There is, nevertheless, another question connected with the development of haploid organisms that is most important. It appears that haploid embryos derived from whole eggs have cells relatively too large in proportion to the nuclei in them, or, in other words, that the protoplasm does not become adjusted in this respect to the chromatin. The weakness of these embryos is sometimes supposed to be the result of such a maladjustment. On the other hand, a fragment of half size with a haploid nucleus would be expected to have the proper adjustment of cytoplasm to chromatin. It has been supposed that they have, therefore, a better chance of survival. The evidence, however, is at present very incomplete, and the conclusion doubtful. A similar question arises in those instances where an egg starts its development with twice the normal number of chromosomes (tetraploid). Geneticists have brought forward several instances of this sort. There is here the reverse cytoplasmic relation. The answer to these two questions may help to solve one of the important problems of development, the quantitative relations of the cytoplasm to the nucleus.

THE RÔLE OF THE INTERNIST IN ENDOCRINOLOGY[1]

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It is a much-appreciated privilege to participate in the proceedings of this section on the 75th anniversary of the association. What a wonderful period this has been in the history of medicine, with the development of our knowledge of bacteriology and parasitology, of infection and immunity, of aseptic surgery, of scientific chemotherapy, and with the growth of a great interest in, and a rapidly increasing knowledge of, endocrinology!

When this association was founded Pasteur had just graduated from the École normale at Paris, Lister was entering upon his student days at the University of London, Koch was a boy five years of age, Robert Graves and Basedow had published their descriptions of exophthalmic goitre, Addison was in the midst of his work on diseases of the suprarenal glands, Brown-Séquard was beginning his experimental work and Claude Bernard was giving to the scientific world his classical statement of the doctrine of internal secretions based upon his work on the glycogen of the liver. What a group of revolutionists! As Sir Michael Foster has said, Bernard's work was revolutionary in more ways than one. He demonstrated that a single organ, such as the liver, may have more than one function to perform, a view that was contrary to the dominant conception of the time, and he introduced the idea of an internal secretion, thus emphasizing the importance of the changes that the blood undergoes as it sweeps through the several tissues, changes that are so important for the health of the body through the coordination of its activities.

Although bacteria had been seen before and theories of living contagion had been formulated, it was the work of Pasteur and of Koch that caused bacteriology to flame out into a great light, which illumined all fields of medicine. The development of endocrinology was less spectacular as it was of less direct utility in the practice of medicine and no great general interest was shown in the subject until after the beginning of the twentieth century. The glands themselves, with the exception of the parathyroids, discovered in

[1] Read before Section N (Medical Sciences), American Association for the Advancement of Science, Cincinnati, Ohio, December 29, 1923.

1880, had been known to anatomists for centuries, and by the middle of the nineteenth century there were on record a considerable number of clinical and pathological descriptions in which were associated certain definite clinical syndromes with lesions of one or another of the ductless glands. Such were the contributions of Flajani, Parry, Graves and Basedow on exophthalmic goitre in the first half of the nineteenth century. Endemic goitre was known to the Romans, its association with idiocy was pointed out by Paracelsus in the sixteenth century and long before that time, Roger of Palermo taught the use of iodin in the form of sponges and seaweed in the treatment of goitre. There were other haphazard observations, such as the description by Felix Plater in 1614 of an autopsy on an infant, a victim of thymic death. Something was known of the influence of the testicular and ovarian secretions through the castration and spaying of animals, which had been practiced a very long time.

Such was the meager state of knowledge concerning the ductless glands in 1848. Bernard's work was just coming forth, Addison's famous monograph concerning the disease that bears his name appeared in 1855, and the next year the experimental demonstration by Brown-Séquard that the suprarenals are necessary for life. Then came in succession the experiments of Moritz Schiff on excision of the thyroid gland in dogs; the surgical excision of goitre in man, by Kocher; the description of myxoedema and its relationship to the thyroid; Schiff's further experiments with the demonstration of the value of thyroid administration in prevention of symptoms in thyroidectomized dogs; and Murray's adaptation of this knowledge in the successful treatment of myxoedema in man in 1891.

Similarly, in the history of pituitary studies it has been the rôle of the internist and the pathologist to correlate lesions with clinical manifestations (Klebs 1884, Marie 1886, Fröhlich 1901) and thus to stimulate experimental work by surgeons (Horsley, Paulesco, Cushing), by chemists and by physiologists (Oliver and Schäfer, Howell).

The gradual unfolding of the importance of the endocrine glands, in the maintenance of health, in the production of disease and in their influence upon growth and developmental processes, began to attract the attention of the whole medical profession, and in the present century the flame of interest in endocrinology has, in the opinion of many conservative physicians, burst forth into a conflagration that seems somewhat difficult to control. It is important to remember that the subject is still in the developmental stage, that in the enthusiasm of the moment there may be

a tendency for fancy to outstrip facts, that the point of view of one internist is not necessarily the same as another's, and that the viewpoint of each is apt to change in regard to certain details from year to year. Our knowledge of the physiology, of the pathology and of the biochemistry of most of the ductless glands is but fragmentary. Much remains to be done and the rôle of the internist in this domain in the course of his practice of medicine and in the clinical investigation of the many problems to be elucidated may be tentatively outlined as follows:

(1) *The clinical observations of endocrine syndromes.*

(a) The diagnosis and treatment of diseases associated with disturbance in the glands of internal secretion.

(b) The clinical trial of the methods used in animal experimentation and of the results of biochemical research that give promise of value in diagnosis and in therapy.

(c) The observation of endocrinopathies under unusual conditions and in unusual associations.

(2) *The clinical study of the constitution in which the endocrine glands must play an important part.*

ad 1—(*a*) Emphasis has already been placed upon the original clinical delineations by internists in this field, and it may be pointed out further, for example, that after the descriptions of exophthalmic goitre by Parry, Flajani, Graves and Basedow, it was Möbius who, in 1886, first attributed this condition to an excessive outpouring of the thyroidal secretion and that the rapid emaciation associated with the disease was explained by Friedrich Müller, in 1892, by his demonstration of the markedly increased metabolism. Similar helpful suggestions and valuable contributions to the knowledge of endocrinopathies are to be expected in the future from the careful observation and study of patients.

In routine office and hospital practice it has been found helpful to include as part of a general diagnostic survey a special endocrine note on those patients who, at the first examination, show features suggestive of endocrine disturbance. In making this note each of the important endocrine glands is considered in turn and under the heading of that gland the positive and the important negative data in each system of the body are recorded. Thus under the heading of the thyroid gland the possibly pertinent data are noted in (1) the endocrine system; (2) metabolism; (3) bones, muscles, joints; (4) the respiratory system; (5) the cardio-vascular system; (6) blood and hemopoietic organs; (7) the digestive apparatus; (8) the urogenital apparatus; (9) the nervous system, including the psyche, the organic neurological features, the autonomic

nervous system, the integument and its appendages. Similarly, in the consideration of the hypophysis, the gonads, the adrenals, etc., the possibly pertinent data are arranged systematically and at the conclusion of the examination an impression from the standpoint of this general survey of the endocrine glands and their functions is recorded. Finally, the integrator of the general diagnostic study attempts to place the proper valuation upon these data as well as upon those obtained by other examinations, to weld the several essential features brought out by the study into a more or less harmonious whole, and to outline the therapy best adapted to the needs of the particular case.

ad 1—(*b*) Although the practicing physician has frequently been the first to point out the association of symptoms with pathological lesions and has passed on to other practitioners this diagnostic ability, in the matter of treatment he is quite willing to come second to him who has "tried it on the dog." Animal experimentation in this as in all fields of medicine has been of incalculable benefit. It is the function of the physician to test thoroughly at the bedside and in the office the therapeutic value of promising methods inaugurated in the experimental laboratories. Thus Murray made the clinical adaptation of Schiff's thyroid substitution-therapy in dogs and showed that in man, also, the administration of thyroid products is capable of replacing, at least in part, the functioning of the normal gland; and thus very recently Best and his collaborators demonstrated the usefulness of insulin in lowering the blood sugar in man and its value as an adjunct in the treatment of diabetes mellitus, after Banting had determined its potency and the means of its control in animals. Would that similar illustrations might be applicable in the substitution therapy of other ductless glands! Much experimental work has been done and many clinical trials made with extracts of the hypophysis, of the suprarenals, of the gonads, and of the parathyroids, with varying results and many diverse opinions. But if this work has given only meager results in supplying substitutive therapy in states of hypofunction of the particular glands it has, nevertheless, increased our therapeutic armamentarium in furnishing several valuable pharmaceutical agents that are useful in the treatment of conditions not necessarily dependent upon hypofunction of the endocrine organ from which the remedy was obtained. As examples we may cite the gratifying results of epinephrin injections in the treatment of bronchial asthma and the equally favorable effects of pituitrin in diabetes insipidus, in dynamic ileus and in cases of sluggish uterine musculature. Banting's recent success in the production of a potent pancreatic extract after years of unsuccessful effort in

many laboratories is most encouraging for the substitutive organotherapy of the future.

In the treatment of patients showing endocrine hyperactivity the internist has learned a great deal from the surgeon, from the roentgenologist and from the radium therapeutist, all of whom have obtained satisfactory results in function-reduction, especially of the thyroid, of the ovaries and of the thymus, although they are less successful in similar attempts to influence hypophyseal hyperfunction and suprarenal hyperfunction. The physician, however, may often secure gratifying results in cases of endocrine hyperfunction, without calling upon his surgical colleagues, by the institution of carefully planned dietetic and hygienic regimens, with due attention to the many small details and with the help of judicious pharmacotherapy and psychotherapy. Much interest is being shown at present in the comparative studies that are being made in several clinics concerning the relative merits of surgical, of roentgenological and of medical methods in the treatment of exophthalmic goitre.

ad 1—(*c*) As an example of clinical acumen in the observation of endocrinopathies under unusual conditions, observations that may perhaps increase our knowledge of glandular physiology and pathology, we may cite the recent contribution of Curschmann upon what he considers the influence of the war diet on thyroid disease. He noticed that in Germany during the war the number of cases of exophthalmic goitre was small, that there were fewer severe cases and that these few recovered unusually quickly on the war ration and did not require surgical intervention. He states, on the other hand, that cases of hypothyroidism were more numerous than usual. Ten of the twelve German clinicians to whom he sent questionnaires replied that their experience was quite similar to his. He attributes the variation in the incidence of the disease to the meager war diet, about 1,500 to 1,800 calories per day, poor in protein (30 to 40 gm per day) and also poor in fat. Each person received from 100 to 200 gm of meat in a week and from 4 to 10 gm of fat daily. Eggs were scarce and there was no cream. His observations and interpretations are at variance with the prevalent custom of prescribing high-calorie diets in exophthalmic goitre. He points out that whereas some clinicians eliminate meat, practically all give a high-calorie diet with much cream. In his opinion, overfeeding a patient with a toxic goitre may cause harmful irritation of the already increased metabolism. He believes that the body worked more economically during the war, that a "sparing system" was automatically set up, and that the thyroid was probably the regulator of this automatic sparing sys-

tem. His interesting suggestions await confirmation or refutation.

ad 2. Practitioners of medicine have always been interested in their patients' constitutions, particularly in their bearings upon predisposition to disease. They repeatedly have occasion to observe that of three children exposed to measles two may sicken and one remain well; that one man deep in his cups may develop cirrhosis of the liver whereas another equally alcoholic may succumb to a peripheral neuritis and a Korsakow's psychosis; that the members of one family die at fifty of cardiovascular disease whereas those of a neighboring household, living under similar conditions, may attain to a venerable age. Thoughtful physicians and laymen have pondered these facts, but during the latter half of the nineteenth century, the attention of scientific medicine was concentrated almost solely upon the study of bacteria and other extraneous sources of disease—with extraordinarily fruitful results—while the study of the constitution was wholly neglected. Indeed, the term came in for some reproach as a cloak for ignorance and as lacking a scientific basis.

With the change in the trend of biological research from the study of the origin of species (evolution) in the preceding century to that of the origin of the individual (heredity and development) in the present century, a scientific basis for a constitutional pathology is becoming apparent, and it is to be expected that in the present generation of workers there will be a closer coordination between medical investigation and fundamental biological research. Biologists teach us that the general principles of heredity and development that have been and are being established through animal experiment are broadly applicable to man and may be used as foundations for medical studies. From those experiments we learn that the fully developed organism (phenotype), in this case the realized adult person, is the resultant of a long series of interactions between the zygote (the fertilized ovum, genotype, idiotype) and its environment; that the "determination factors" (ids, genes) of development are contained within the germ and that the "realization factors" of development lie in the environment; that both factors are necessary for development, which is, however, governed mainly by heredity.

Professor Conklin explains graphically by his figure of the shuffle and deal of the chromosomes the almost infinite possibilities of hereditary differences. Considerable variation in human beings is, of course, compatible with health, though each variation may be associated with some special predisposition to disease, and it is reasonable to believe that the study of such individual variants may lead to the development of special, as contrasted with general, prophylaxis. Such variants may manifest themselves by morpho-

logical distinctions, by physiological differences, by differences in the evolution or involution of development, etc.

Experimental studies upon the influence of endocrine products upon growth in early stages of the development of certain larvae and clinical observation of the effect of endocrinopathies upon the physical and mental development of human beings make it seem probable that, in the developmental processes of both normal and abnormal phenotypes, the internal secretions may play an important rôle. It seems possible, as Barker has said, that the genes, or determiners, of hereditary characters may, to some extent, at least, operate through the mediation of the endocrine glands in the production of varieties among phenotypes, including perhaps those pathological personal variants that fall victims to diseases the etiology of which seems at present quite obscure. It is certain that the rôle of the internal secretions must be strongly considered in any systematized study of the pathology of constitution. It has been pointed out that the diseases of the endocrine organs, especially those that develop insidiously and give rise to the classical endocrine syndromes, appear to be usually of endogenous rather than of exogenous origin, that is to say, they develop as the results of special anomalies of constitution. Endocrinopathies tend to run in families and perhaps the interrelationships between the glands may account for the fact that all the cases in one family need not be of the same general type. There are criteria by which one may recognize or suspect, for example, a thyreotoxic constitution, a hypothyroid constitution, a hypopituitary constitution or a hypogenital constitution, and in certain cases suitable prophylactic measures may be instituted. We may cite, as probably the most striking example, the hypothyroid state in which the definite clinical criteria and the basal metabolic rate furnish a reasonably satisfactory scientific basis and in which suitable prophylaxis may prevent or ameliorate distressing symptoms that might otherwise arise from any or from all the body systems.

Your attention may be further directed to the extensive prophylactic measures now being adopted for the prevention of simple goitre; to the report by Bramwell (1908) of the demonstration of recessive heredity in a glycosuric family; to Gossage's report of dominant heredity in a family exhibiting diabetes insipidus; and to the contribution by Lenz (1917) who cites evidence of a dominant, partial sex-limited heredity for the thyreotoxic constitution which he believes may account for the preponderance of incidence of exophthalmic goitre in females. These citations illustrate the growing interest of clinicians in the relationship between the endocrine organs and the pathology of constitution.

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BAIRD THE NATURALIST[1]

By Dr. C. HART MERRIAM
SMITHSONIAN INSTITUTION

A CENTURY ago to-day was born into the world a babe destined to develop and organize the natural sciences in America and to become the teacher and leader of the upcoming generation of naturalists—one whose modesty, simplicity, sincerity, industry and masterly accomplishments were to become an inspiration to fellow-workers.

The time was opportune. Coming into manhood at a period when our fauna was little known and the literature fragmentary and scattered; possessed of vigorous body, a clear intellect, sufficient ambition, and an unquenchable love for natural history, he early perceived the opportunity and need for original research and threw himself body and soul into the field.

Confronted with the unsatisfactory state of the best works on zoology, with special reference to the vertebrates, and with the incompleteness of museum collections, he saw at once the pressing need of gathering the raw materials, and became of necessity a collector of specimens—for without specimens how could he study and classify the birds, reptiles, batrachians, fishes and mammals in which he had already become so acutely interested.

He began at about the age of 15, the period of maximum youthful enthusiasm, and from that time until overwhelmed by the pressing duties of the assistant secretaryship of the Smithsonian in 1850 continued his search for specimens with ever-increasing eagerness. And one can not but be amazed at the magnitude and diversity of his collections.

It is a matter of record that when 27 years old he had accumulated 3,500 skins of birds, upwards of 500 glass jars and numerous barrels, kegs and tin vessels of reptiles, 600 skulls and skeletons of North American vertebrates, a number of embryos "in pickle," and large collections of fossil bones from the bone caves of Pennsylvania and Virginia.

This enormous collection when shipped to the Smithsonian in

[1] Abstract of address at the Centennial Anniversary of the birth of Spencer Fullerton Baird, held in the National Museum February 3, 1923. Two prominent sources of information have been freely drawn upon: Goode's "Bibliography of Baird," 1883; and Dall's "Biography of Baird," 1915, the latter containing a multitude of Baird's early letters and other important data.

October, 1850, filled two railway cars and became the nucleus of the National Museum.

Birds were his first love, followed closely by reptiles, and a little later by mammals and fishes, all of which continued to occupy his affections to the end of his life. Birds, mammals, reptiles and batrachians were the subjects of his most elaborate and important contributions to science. He began to publish descriptions of new species of birds in his 20th year, and a year later brought out an important faunal paper on the "Birds of the Carlisle region." In 1845 he published his only strictly botanical paper, treating of the trees and shrubs of the same region; followed in 1849 (when he was 26 years old) by a most important original "Revision of the North American tailed-batrachia," and soon after by "Descriptions of new salamanders," and a paper "On the Bone Caves of Pennsylvania," after which until near the end of his life his contributions, appearing at frequent intervals, covered a wide field.

Before the close of his 18th year, in order to acquaint himself with what had been written on the natural history of America, he had searched the public and private libraries of Harrisburg, Philadelphia and New York for volumes not available at Carlisle, and in 1846 had visited Boston and New Haven for the same purpose. It is known that he once—and inferentially several times—walked 40 miles to Harrisburg and back in a single day, carrying a load of borrowed books and bringing back fresh ones.

Baird as a young man was strong and well developed, more than 6 feet in height, broad shouldered and good looking. He was a famous walker, and on one of his excursions, though encumbered with gun and knapsack weighing 25 pounds, walked 400 miles in 21 days, and on the last day no less than 60 miles in 18 hours (walking time exactly 15 hours); and during the year walked upwards of 2,200 miles.

In November, 1841, he began studying medicine in New York under Dr. Goldsmith, but medicine proved not to his liking and he soon returned to Carlisle.

While he was in New York Dr. Goldsmith, who evidently was very fond of him, took him to see Audubon, with whom he had corresponded for several years. Other distinguished naturalists met in New York were George N. Lawrence, the eminent ornithologist, Titian R. Peale, of the Wilkes Expedition, James DeKay, author of the large volumes on the natural history of New York, J. P. Giraud, author of "The Birds of Long Island," and John G. Bell, the leading taxidermist of the time and later a companion of Audubon on the Upper Missouri expedition.

In 1842 he was urged by Audubon to accompany him on his

expedition up the Missouri River to the Yellowstone, but owing to the fears of his mother and other relatives, declined.

In 1845 Baird was appointed professor of natural history and curator of the cabinet in Dickinson College at Carlisle, Pennsylvania, without pay; the following year he was granted a salary of $400, which in 1847 was raised to $650, and in 1848 to $1,000. On beginning his work as teacher he instituted a series of outdoor excursions on Saturday afternoons in the course of which natural history collections were made. This was of great practical assistance to the students, and although in accordance with a widespread custom of to-day, was at the time "a startling innovation." (Lucy Baird, in Dall, p. 145, 1915.)

By this time Baird had mastered several foreign languages. In 1845 he was reading German and had begun Italian and Spanish, and early in 1847 he began Danish. In addition to readings for his own use he had done a large amount of translating, especially from German, for Audubon, Cassin and Dana. In 1848 he undertook the translating and editing, involving the rewriting of many of the chapters, of a very pretentious work—the "Iconographic Encyclopedia"—which appeared in installments, the first four numbers in 1849, the completed volumes in 1852.

Throughout the forties his frequent letters to his brother William teem with ornithological details, for during this period he was not only collecting birds most vigorously and had been given many rare species by Audubon, but also was exchanging specimens with both American and European ornithologists.

In January, 1847, acting on a suggestion from James D. Dana, Baird applied to Professor Joseph Henry, secretary of the newly established Smithsonian Institution, for the position of curator. But the funds of the institution available for science were at a low ebb, owing to large expenditures for the construction of the building, and it was not until July, 1850, that he was elected assistant secretary of the institution.

Then, when actually installed in this coveted position, his head bursting with the dream of a great national museum, his efforts to secure specimens were redoubled.

Again the time was opportune, for the government was just beginning its famous series of Pacific Railroad surveys, in the hope of finding a practical route from the Mississippi River to the Pacific.

Not only were these several expeditions equipped by Baird with collecting outfits, not only were one or more men on each instructed for the work, but in most cases the choice of the naturalist or surgeon-naturalist was delegated to him.

This was his golden opportunity, and he utilized it to the utmost,

calling on friends and correspondents at home and abroad, and setting in motion the ponderous machinery of the government—the army, the navy and the civilian branches—to aid in bringing in materials. His method was not that of the *official order* but of the *personal appeal.*

And when one finds among his devoted helpers such luminous names as those of Farragut, of the navy, and of Abert, Abbot, Emory, Ives, McClellan, Marcy, Simpson, Sitgreaves, Scott, Thomas, Whipple and Williamson, of the army, and of such surgeon naturalists as Drs. J. H. Clark, C. B. R. Kennerly, Wm. Gambel, J. S. Newberry, George Suckley and Samuel Woodhouse—one may perhaps realize something of the extent of his acquaintance, the keenness of his knowledge of men and the far-reaching persuasiveness of his personality.

The resulting inflow of specimens and new information, pouring in in ever-expanding proportions, was no less than overwhelming, involving a great increase in the correspondence, great labor in keeping collectors supplied with equipment, and—most important of all—necessitating an immediate preliminary examination of the collections, for field naturalists are impatient to learn the value of their contributions and must of course be encouraged.

But this was by no means all, for since at that time little was known of the natural history of the west, a large proportion of the species sent in proved new to science and had to be worked up and described; moreover, the reports of the field naturalists had to be corrected, edited and sometimes rewritten.

The whole country was alive to the importance of these transcontinental expeditions and eager for the results, so that prompt publication was a necessity. And Baird's share in the preparation of the resulting thirteen fat quarto volumes with their attractive maps and illustrations was enough to occupy an ordinary man a lifetime.

But Baird was no ordinary man.

He saw that the time had arrived for a complete overhauling and rewriting of the technical monographic works on the various groups that go to make up our terrestrial fauna, and was ready and eager for the opportunity. Realizing perhaps that he was the best qualified person in the world for the task, he accepted as his share the preparation of the volumes on birds, mammals and reptiles. Labor of this exacting kind demanded, but could not possibly receive, his entire time. His days were crowded with the pressing duties of his position at the Smithsonian, so that his scientific work had to be done at home and at night. Five years previously, in a letter to his friend George P. Marsh, he had spoken of working 12

hours a day in winter and 15 in summer, but during the rush and pressure of the Pacific Railroad reports these long hours were materially increased. And it is a matter of record that in the case of his renowned monographs of American mammals and birds, the text written one night frequently came back in proof the next, while at the same time new text had to be continually supplied, with no opportunity for the checking and revision of manuscript which most of us find so essential.

One can not but envy the reserve power and intellectual strength that enable a man to cope successfully with an emergency of this character.

Baird's great monographs set the clock of knowledge far ahead, laid a higher foundation for future research, and at once took their place among the classics of systematic zoology. Probably no works by a single author ever exerted so stimulating an influence on the naturalists of the time.

With the appearance of the volume on birds in 1858 began what the late Elliott Coues designated the "Bairdian period of American ornithology"—a period that continued for nearly 30 years "and was characterized by an activity of ornithological research and rapidity of advancement without a parallel in the history of science." And our colleague, Dr. Leonhard Stejneger, writing nearly 40 years ago, contrasted what he called the "Bairdian School" with the older "European School," pointing out that while the latter requires the investigator to accept an author's conclusions on the strength of his word alone, the Bairdian school furnishes the facts from which one may draw his own deductions.

Turning now to a later period (the early seventies) when Baird's major activities had been transferred from the land to the sea, a new impetus was given the study of aquatic life, and it came to pass that under his guidance the knowledge of marine faunas grew as had previously grown the knowledge of terrestrial faunas, until the living things of both the lands and the waters of North America came to be better known than those of any other part of of the world.

Baird was of the type that make the best naturalists. Beginning as a field collector and student of birds and soon expanding his interests to include reptiles, batrachians, fishes, fresh water mollusks, fossil shells, fossil bones, mammals and plants, he acquired a deep understanding of the fauna and flora of his home region, which in turn created a thirst for broader knowledge, leading to collecting trips in many states, to exchanges with many lands, to the bringing about of natural history explorations in the far west and far north, till his collections overflowed with representatives of the major part

of the vertebrate fauna of the continent. In his studies of this material he became the keenest, ablest and most authoritative of American writers on vertebrate zoology. No other person had ever combined in equal degree the qualities of the successful museum man with the high scientific attainments of the monographer of groups.

It was fortunate for him and for us that he lived in—if in truth he did not bring about—the period of greatest activity in the history of the development of the natural history sciences in our country.

We know the value of his personal contributions to systematic zoology, but we may never know the extent to which the progress and dignity of science in America are due to his influence and wisdom, especially in his relations with influential government officials during the 38 years of his service in the Smithsonian Institution and Fish Commission.

Nor can we measure the results of his encouragement and helpfulness in shaping the careers of the younger naturalists, some of whom, no longer young, are present this evening. For no matter how busy—and he always was overwhelmed with work—Baird never begrudged the time given to the encouragement of young men who were really in earnest. Most American naturalists of the generation now all too rapidly drawing to a close owe to him at least a part of their training and much of their success, and realize how great a privilege it was to have been enrolled under his leadership.

On an occasion of this kind one may be forgiven an indulgence in personal reminiscences. I, in common with perhaps two or three other naturalists here present to-night, owe to Baird much of whatever we may have accomplished, particularly with reference to his advice and assistance in shaping the early part of our careers.

It was Baird who, 52 or 53 years ago, asked me if I would like to go West on one of the government expeditions, in reply to which I confided to him that such was the ambition of my life; and a year or two later (in March, 1872) he notified me that I had been appointed naturalist of the Hayden survey of the territories, in the course of which it was my privilege to visit the far west and make collections of mammals and birds in the little known territories of Utah, Idaho, Wyoming and Montana.

After my return it was Baird who gave me every facility for work in the Smithsonian building, and in the spring suggested a collecting trip to Florida, which I made early in 1873. This was in part an offset, for Baird knew that I had set my heart on accepting a position on the Wheeler Expedition, to which my friend

Henry W. Henshaw had been attached the previous year. Baird had dissuaded me from going, insisting that if I went I would probably continue to go year after year and remain a *collector* of natural history specimens rather than become a trained naturalist. Instead, he urged me to go to the Sheffield Scientific School of Yale, where I would have the advantage of laboratory work and lectures on zoology under Verrill, and in botany under Eaton. His advice, in which my father concurred, was followed, and in 1875, while I was still at Yale, he appointed me an assistant in the invertebrate laboratory of the U. S. Fish Commission at Woods Hole. Here, by a fortunate combination of circumstances, Samuel F. Clarke (later professor of zoology in Williams College) and I were put in charge of much of the season's work with dredge and trawl on the steamer *Blue Light*, and in the laboratory had the privilege of working alongside of Alpheus Hyatt, Sidney I. Smith and Tarleton H. Bean.

A year or two later it was the combined influence of Baird and Verrill that prompted me to draw out from the Utica Savings Bank all the money I had in the world in order to make a collecting trip for rare invertebrates in the Bay of Fundy, taking with me Edmund B. Wilson, then a boy, now DaCosta professor of biology in Columbia University.

Again it was Baird who induced me to collect fishes in the Adirondack region of northern New York and provided part of the necessary outfit. Still later it was with his cooperation that I visited the Newfoundland and Labrador seal fishery as surgeon on the sealing steamer *Proteus*. And finally, it was his influence more than that of any other one person that induced Congress to make the initial appropriation for ornithological work in the Department of Agriculture, beginning July 1, 1885, which later developed into the present Biological Survey.

Those of us who were closely associated with Baird are sure to recall many acts of thoughtful kindness. One of these occurred during the winter of 1872–73 when G. Brown Goode and I were working in the basement labyrinths of the Smithsonian. Suddenly, to our astonishment and joy, Professor Baird appeared, bringing the renowned Louis Agassiz down "to see what we were about!" Here, standing beside us, were the two greatest living naturalists; the two who had done most to encourage young men and to advance the study of natural history in America—the two men in all the world upon whom we looked with greatest reverence.

In natural history, as elsewhere, there are guideposts to direct the steps of the explorer. Some of these in America—pillars rising conspicuously from the broad plain of knowledge—were Audubon,

Agassiz, Baird. Sir John Richardson deserves a place among them, but his researches were restricted to the far north.

Audubon was the pioneer, and while his personal labors were in the fields of ornithology and mammalogy, the genius of his writings and the magnificence of his paintings did much to arouse general interest in the natural history sciences.

Agassiz combined two quite distinct qualities—those of the patient investigator and the popular lecturer, and with his genial manner and pleasing address, did more than any other man, before or since, to popularize the study of natural history.

Baird, on the other hand, while a wise councilor and a born organizer and leader, was personally so modest and shy that he never appeared on a public platform; a man of tireless energy, an enthusiastic collector, a critical student, and able delineator of the characters of animals, the best informed man in the world on the vertebrate faunas of North America, he became, as summarized by the Encyclopedia Britannica, "the most representative general man of science in America."

That it should fall to the lot of one man to rise to the highest eminence in science as a result of the value of his own contributions, and that this man should be chosen to occupy the highest position in the gift of science, is not in itself so strange; but that the personality and influence of this same man should prove so stimulating and far-reaching as to create an army of enthusiastic workers in the various fields of natural history, that it should enlist in behalf of his projects a multitude of civilians and high officials of the government, and that it should move the Congress of the United States to do his bidding, is a thing unprecedented in the history of science.

BUSINESS STRATEGY IN NATIONAL AND INTERNATIONAL POLICY[1]

By Dr. JOHN F. CROWELL

STRATEGY is another term for planning. The planning implied in the military use of this word has attained a degree of scientific thoroughness which might well be applied to the peaceful pursuits of commerce and industry. It should not, however, be assumed, as is sometimes done mistakenly, that commerce is war. Commerce is peace, because it is service—service mutually beneficial to both the seller and the buyer. Each party to the commercial transaction has added to his wealth by the exchange, whether it be money for goods or goods for goods, as in barter.

The world market is the field of service within which commerce and industry engage in their ministration of increasing one another's wealth and welfare. Let us, therefore, discard at the start the cutthroat conception of commerce and industry as abnormal in considering the application of the principles of strategy to business enterprises. We are justified in making this plea because the *morale* of economic life has made gains in many directions within comparatively recent years. The brutal instincts of commercial highwaymanship have lost caste in favor of the serviceable ministry of mutually beneficial salesmanship.

From this viewpoint let us consider what is involved in the strategic organization and operation of a business enterprise whose field is the local market, the regional market, the domestic or national market or even the world market. For the scientific principles of mercantile and industrial strategy are applicable to units of any size. They are equally applicable to the manufacturing or industrial unit of enterprise and to the commercial organization engaged in mercantile distribution. Nowadays so many of the manufacturing industries engage in direct selling of their products as to make it necessary for them to be salesmen as well as industrialists. In fact, manufacturing which is always producing for a market is never safe without taking the selling capacity of its products on their inherent merits into account. Planning systematically involves both making and merchandising as complemental parts of the same economic process.

[1] Address delivered at the Cincinnati meeting of the American Association for the Advancement of Science, before the Section on Social and Economic Sciences, December 28, 1923.

I. The Four Principles of Strategy

Business strategy is long-term planning based on scientific surveys of the field and its essential factors. Systematic planning in economic enterprises makes it essential to seize upon the main factors at once. He who can not draw a clear line of cleavage between the essential and incidental in a situation has no business in the field of strategic planning. Likewise, to insight must be added the aptitude of foresight. To foresight and insight add hindsight. Hindsight is another name for history. He who would plan strategically a campaign for a locomotive manufacturing industry for the home or the foreign markets without knowing something of the main points in the history of locomotive selling at home and abroad would simply be another case of the half-blind leading the blind. It might be better than nothing, but it is not the best that can be done. The same applies to any other industry, any mercantile house, and to transportation systems or any banking concern. They all need strategy to realize their possibilities. Their success is measured by the strategic capacity of the personnel on whom management devolves.

(1) *The Principle of Position.* The first principle of business strategy is to ascertain in the fullest practical manner the actual position of an enterprise which is to be made the subject or basis of this systematic planning. If it be a manufacturing plant, which has grown up locally, for example, and has come into the hands of people who believe that it has a larger destiny than the local market, it must then be ascertained as to whether that class of industry is of the kind which ever gets beyond a given radius. An iron foundry, for example, produces products of such bulk in weight as to limit its market to a very definite radius of transportation costs. Silk products, on the other hand, are subject to no such condition. You may, however, have a chain of iron foundries reaching around the globe. But in either case the facts of position with reference to marketability lie at the bottom of strategic planning. The nature of the product is therefore the first strategic element in defining its actual position. Once defined, it helps to settle other questions in the same field.

The principle of position calls for a second fact in the form of the competitive relation of the product. Has it a field of its own, so that it need not divide the market with one, two or ten competitors? The basic factor in competition is costs. A Paterson silk manufacturer worked for five years in the improvement of his manufacturing processes to a point at which he felt confident that he could operate profitably when every other competitor had closed his mill. In due time, the silk trade said of his establishment that

it was the only one that was making money. This illustrates the fact that strategy begins, or at least is vitally centered, at the factory. Competitiveness of a product covers a much wider field than what has here been designated. It includes financial position, both actual and potential. It likewise embraces selling capacity. In fact, the whole content of the manufacturing plant's experience has to be laid on the table to show what sort of a hand the player has with which to win his game.

Strategic position involves geographical re-location, if necessary, for a contemplated campaign. An ocean-going shipbuilding establishment should not be located on any of our great rivers or on the great lakes except it be near the mouths of rivers with short and direct access to the sea. These things are self-evident. Such is the Delaware shipbuilding area—our leading district of the kind. It is not however so apparent where a plant should be located which manufactures both for the domestic and the foreign market. Take automobiles, in which we lead the world's exporters. The planning of one of the largest of these manufacturers has resulted in shifting the export division of the industry across the border into Canada, primarily for two purposes: (a) To avoid retaliatory treatments of his products in foreign countries; (b) the desire to profit by the imperial preference duties on foreign imports into the United Kingdom of Great Britain, her dominions, her colonies and her other dependencies.

From this it is evident that the worldwide market imposes certain conditions on the location of industries which aspire to a place on the map of the world. It is also evident that the type of man needed for salesmanager is not one of the swivel-chair, single-track minded type, but rather a man with a head capable of entertaining a competent grasp of international economics.

II. The Principle of Communications

Business strategy involves the careful study of the lines of communication and transportation from two points of view: first, where and how to get the commodities or the raw materials and the manpower necessary for the progressive development of the business. For with the expansion of markets there will come constantly widening demand for output to meet the multiplying customers. Therefore, the question of access to the markets for labor and materials is vital. Not a few industries whose success was achieved in districts where anthracite fuel was once available have found it necessary to move within the radius in which more economic fueling could be insured, whether from bituminous coal, from coke, from water power or from hydro-electric sources of supply.

Such was the Lackawanna Steel Plant which moved from Scranton to Buffalo, in order to gain the advantage of low-cost transportation on iron ore and on fuel, the former coming down the lakes from the Minnesota orebeds.

The second viewpoint from which communication must be considered as a factor in strategic planning is that of transportation to markets. Is it better to have a plant at the seaboard to manufacture both for the populous districts in the home market and for the export trade? Something depends on whether the market is to be of continental or of universal scope. If you seek to serve European markets and Mediterranean countries, then the North Atlantic coast has several good outlets. Avoid a port whose traffic facilities are congested a good deal of the time under existing conditions of traffic management. An uncoordinated system of putting streams of merchandise for export through the neck of a choked-up bottle is rank folly.

On this question of selecting the export gateway through which one's shipments to foreign markets should move, the western flour manufacturers, by means of the through bill of lading, and special arrangements with the port authorities of Philadelphia have special piers through which they get the most direct movements between the mills at home and the importing merchants abroad. Baltimore likewise and also Boston command export products throughout the interior traffic areas with which they have good connections. Of these any manufacturer can avail himself. But it is necessary that he should know the strategic relation of his rail-and-water connection between himself and his market as a means of saving in the cost of distribution.

This second principle of communication applies to importing as well as exporting. The properly equipped department store which imports porcelain goods from an Austrian factory is not master of the situation strategically unless its traffic manager knows the more advantageous routes of shipment, whether by rail inland to the Mediterranean or north to the Atlantic for ocean transport to the United States by way of the port which is most economical in its treatment of hinterland goods.

Something should be said of the industry or the mercantile house which serves only the domestic market. Some of the large retailing, wholesaling and jobbing centers of the country are more advantageously situated than others. But few of them have looked thoroughly into the question of such combination of shipping rates, by water and rail, as will enable them to reach the same markets at lower costs or newer markets at costs which admit of profits. Here is a field for the traffic specialist in cooperation with the

traveling salesman under the same salesmanager. A compilation of the facts is a clerical task. The proper use of them requires strategic talent. Without such data, developing markets is a speculation; with such data rationally utilized the expansion of markets becomes a science of merchandising.

III. The Principle of Adequate Resources

In planning a campaign strategically time is an element. A plan which peters out for lack of resources in two years but which might well have won out if there had been enough resources for carrying on during a period of four years is manifestly an evidence of bad generalship. The plan of campaign for any enterprise must first lay down the size of its problem. We intend to put our fabrics, or our patent food, into the West Indian and Caribbean territory by building a well-established sales organization so as to cover every essential point or community. How long it will take is secondary to the question of what amount of resources will be needed (a) in the equipment of the home base, (b) in the sales organization to be maintained and (c) in the incidental expenses in personnel and capital for changes in condition and meeting extraordinary events.

This latter point may be illustrated by the collapse of prices and the utter breakdown of credit relations which occurred in the years 1920 and 1921 in American trade relations with South and Central American as well as West Indian markets. In this case, resources were found to be wholly inadequate, as measured by reserves set aside for emergency conditions. It was a wise employer who when engaging a salesmanager put as a final test to the applicant, "How many commercial and financial panics have you been through?" For a salesmanager who has never weathered a panic is after all but a fair weather captain. Many of us may be too young to have passed through this scope of experience; but there are thousands of business men living who can be interviewed on their experiences, and there are hundreds of books and published official documents full of information. Annual reports of corporations publish valuable information. So that there is no possible excuse for the export manager to live in ignorance of conditions that at any hour may engulf him and his business for want of ordinary foresight.

IV. The Fourth Principle: the Selection of the Objective

This principle gathers into its scope lines that reach out from the other three. In business strategy the selection of the objective

is really the first and foremost of basic factors involved in industrial and commercial planning. This includes the following elements:

(1) What is it that is to be manufactured or marketed?

(2) What is the actual production and the extent of competition in the commercial distribution of the specialty in question?

(3) If the market hitherto has been only regional or domestic, that is, national in scope, would it be good business policy to extend the market into other continents, unit by unit, and could the manufacturing capacity be expanded to meet such a program?

(4) If international expansion by continental units were deemed desirable, what system, systems and methods of export merchandising could most advantageously be used in selling abroad from the home manufacturing base?

(5) If surveys and research into these conditions and problems were found to justify going ahead on the lines indicated, from what sources could adequate financing be provided for say a ten-year program of expansion?

(6) Where and how could a competent personnel be found or developed to meet the gradual or rapidly enlarging scope of business involved in this program?

All the above lie within the scope of determination of the business objective before a single step is taken in any other problem. The answers to these questions will leave little that is necessary for future inquiry within this principle. But having determined these facts properly, the ascertainment of data embraced in the other three principles will be much simplified.

V. Business Strategy the Key to Post War Reorganization

Scientific business planning, in which traditional sentiment, business nepotism and political meddling of all kinds are subordinated to the problem of permanent reorganization of industry and trade, is really the next great step in the national evolution of our business institutions and in their better adaptation to world-wide service. Some of our best concerns have already taken this step and are prepared for business in any part of the world market, near home or in far Cathay. But the vast majority have been half asleep on the comfortable berths which they sought to make for themselves in the transitional readjustment following the war. Thousands of enterprises have thus built on the sandy foundation of inflated values and other follies of business self-deception. It is nothing short of the falsification of fact to say that there has been an honest, enlightening and thorough-going reorganization of business since 1920 and 1921. On the contrary, as every official in the

Internal Revenue Office at Washington knows and every accountant who has had to do with the income tax should know, too many people in the manufacturing and commercial, the financial and the transportation worlds have been preoccupied in the task of belittling the taxable content of their business assets. If the business world had devoted an equal amount of attention to an honest-to-goodness reorganization of business, instead of covering up weak spots, decayed branches and otherwise unhealthy symptoms, the business world as a whole in the United States would not be headed, as some are now convinced it is, towards its day of reckoning with over-inflated values.

VI. Is Commerce Overloaded with Personnel?

I raise another question whether we are not building up a badly balanced economic organization in our national life by overloading our distributive machinery, including commercial and financial organization, railroads and shipping, as well as the administrative functions of government, with far more people than can be productively employed; while, on the other hand, we are draining away from the tillage of the soil, from the working of the mine and in thousands of places from the smaller industries of towns and villages the labor which is paid approximately by the value of what it produces.

General Francis A. Walker, one of the foremost American economists, many years ago called attention to this tendency in American economic life on the part of the distributive organizations to overgrow their normal capacity and become crowded with manpower at the expense of the extractive and manufacturing industries. Nowadays manufacturers are merchandisers as well. Have we not again reached such a stage of development in which the distributive and some of our manufacturing organizations have competed unduly for the labor supply and thus created a situation of uneconomical production costs with regard to the consuming world?

The answer is that not a few manufacturing establishments typical of conditions in the textile and the electrical industries have gone on making goods and piling up stocks at a cost basis which is forcing them out of touch with what the consuming world is willing to pay for them. If the truth were known, there are more of these than it is well for the country to have when everything but farm products generally is at an unhealthily high price level.

Whether the existing gap between manufacturing costs and consumers' purchasing power is likely to widen or close up remains to be seen. But this situation is one of the big problems of domestic

industry. Nor is it confined to the home market. If its existence is to be more or less removable, the best of business generalship on the part of our leaders, including bankers, manufacturers and merchants, will be necessary. In other words, when you are rebuilding a bridge on a railway line, displacing an unsound wooden one by a more effective steel bridge, you need the best kind of engineering talent to prevent trouble.

VII. The Great Unsolved Commercial Enigma

The position of the United States as a unit in world commerce presents at this time one of the most important problems which has ever confronted us in our international relationships. Our home market is prosperous, partly by reason of its great scope and unmatched volume of popular purchasing power. But we are now a surplus exporting country whose agriculture has already felt the damaging effects of unfavorable foreign markets. The world market is the price determinant for staple agricultural products. As for cotton, thanks to the boll weevil, the world market price is all that could be desired, but for grains and meats, the outside world is underselling us. If this is to become permanent our scale of production must do one of two things. It must either adapt its production to the protected home market or it must find ways and means by which to market its surpluses profitably in the world market. Such a readjustment is more than incidental—it is fundamental and far-reaching as a policy in its effect upon our social and economic life.

The great unsolved problem, therefore, consists in the adjustment of the home market built up and maintained on a price level out of line with the prevailing price levels and purchasing power of the non-American world. We are at the crossroads of commercial destiny. Shall we adjust the home market to the world market, or shall we rack our brains to fortify ourselves by devising new methods for a more intensive and complete national isolation?

VIII. A Task for Business Generalship

If our home affairs as such need attention, rather than our outer relations, what, then, is the real task of business generalship in the existing economic situation? What we need most is a searching examination, industry by industry, trade by trade, into every organic division of our national life, such inquiry to be based on scientific surveys of the structure and functions of each such division. Such a survey has recently been made into the coal industry, and we are getting at the facts of the false situation resulting from the deadlocking of the industry in restraint of trade.

The business strategist is rapidly taking the place of the captain of industry, especially in large scale industrial and commercial enterprises. The old-type industrial captain has not had the breadth of vision nor the grasp on tendencies old and new to survive. Strategy, according to this exposition, means business planning based on scientific surveys of a concern's objectives, resources, connections and internal conditions. The captain of industry is gone or has gone, and in his place are found divided responsibilities among at least three divisional leaders—the salesmanager, the cost accountant and the financier. The specialist has captured the captain's stronghold and the strategist has become the general in chief. Normally headship of business seems to be passing into the hands of a central executive committee functioning really as a Board of Strategy. The logical head of that board is a chairman graduated from the position of president at divisional counsels where the details of practical operation had occupied his attention. As chairman of the board of strategy questions of principles and policies occupy his entire thought and effort, leaving details and specialization to the divisional leadership further down.

The application of the principles of economic and social science to surveys of markets, sources of raw material, processes of specialization, methods of commercial distribution, warehousing, insurance and financing as well as shipping and transporting, if carried out in the hands of competent strategic talent, should put us in position to compete with the world in all lines in which we are entitled to succeed.

PAINTING THE TOWN RED[1]

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THE first example noted in the New English Dictionary is: 1884, Boston, Mass., *Journal,* 20 Nov. "Whenever there was any excitement or anybody got particularly loud, they always said somebody was 'painting the town red.'" Two other examples are: 1897, *Chicago Advance,* 15 July, "The boys painted the town (New York) red with firecrackers (on Independence Day)": 1900, Capt. M. H. Hayes, *Among Horses in Russia,* London, I, 36, "I have found them in no way inclined to paint town and country red on the slightest provocation."

In the *Century Magazine,* vol. 36 (1888), p. 838, in an article "Frontier types," the writer says: "All this is mere horseplay, it is the cowboy method of 'painting the town red' as an interlude in his harsh, monotonous life." The expression is faintly criticized in *The Nation,* Feb. 1, 1906, p. 105, in a review of Rev. T. H. Passmore's "In Further Ardenne," London, 1905, "We may have no reverence for Louis XIV, but our feeling finds imperfect reflection in the description 'painting the closing decades of the seventeenth century red.'"

The *Literary Digest,* March 24, 1906, quotes from a review in the London *Times* by Mr. Walkley of Mr. Stephen Phillips's *Nero*: "Its hero is Nero, the esthete, the 'artist in omnipotence,' who uses human gore for his pigment and for his canvas the world. To speak more colloquially, he is the debauchee who paints the town red, not for the sake of debauch, but to gratify his taste for vivid color."

In *Notes and Queries,* viii series, vol. iii, p. 126, 1893, there is an amusing note: "Slang: 'Paint the town red':—'I say,' suggested George, 'I have finished my book and you have nothing to do. Let us pack up our traps and go to Paris and paint the town a vivid scarlet.' 'What?' asked Jonah Wood, to whom slang had always been a mystery. 'Paint the town red,' repeated George, 'In short,

[1] I was quite surprised to read in so serious a journal as *The Times Literary Supplement* for October 25, 1923, the following use of a slang expression generally regarded as of American origin. "It required all the strength and wisdom of Lord Salisbury to stave off the dangers into which we were rapidly rushing at the time when it appeared to be the ambition of the nation to paint the whole world red." It has occurred to me that a study of the expression and its possible origin might be of interest at this time. The materials for this paper were collected some years ago, but the article has never been published.

have a spree, a lark, a jollification, you and I.' " "The Three Fates," by Marion Crawford, 1892, p. 386. The writer of the note then continues: "To paint the town red seems generally to be considered modern slang from America; but if Jonah Wood had known his Shakespeare he might have got some light by recalling Prince Henry's narrative of his friendship with the leash of drawers, of whom he says: 'They call drinking deep, dying scarlet' (*I Henry IV*, ii, iv). Is there anything modern Shakespeare did not anticipate?"

I have not time now to multiply examples and it is not necessary for my present purpose, but I can not refrain from citing a curious book which shows the spread of our expression, and, incidentally, the remarkable way in which the Germans and their kin the Dutch find material for their dissertations and monographs. The book in question is "Studies in English, written and spoken, for the use of continental students, by C. Stoffel, Zutphen, 1894." Pp. 170–272 contain an article, "Annotated specimens of ' 'Arryese,' a study in slang and its congeners." The article is based on letters in verse which appeared in *Punch* in 1877 and later. Mr. Stoffel says, p. 222, "What in Dutch is vulgarly called 'den boel (de peentjes) opschleppen,' is in the 'Arry dialect known as 'painting the town red,' equivalent to, being on the spree, out larking," etc. *Punch*, Jan. 24, 1885, "Christmas is over and gone in every sense, for we have all been half-seas-over, and all our money is gone. . . . We have painted the town red and no mistake"; *Judy*, Oct. 20, 1886: "Something to re-arrange his nervous system as he was busy painting the town red last night"; *Punch*, June 4, 1887: "To climb up a lamp-post and paint the town red"; *Punch*, June 25, 1887 ('Arry on the Jubilee): "The town's painted red, I can tell you, a regular flare-up and no kid"; *Punch*, same date ("A Baboo's attempt to write a jubilee ode"): "For we greet the fiftieth recurrence—Of the day our Queen the throne ascended—With a solemn universal high jinks—Painting the town red"; *Judy*, March 14, 1888: "Spenser turned up from Ireland and Walter Raleigh, and he and I painted the town red like R. A.'s"; *Punch*, May 7, 1892 ('Arry on Wheels): "My form (at bicycling) is chin close on the 'andle, my 'at set well back on my 'ed,—And my spine fairly 'umped to it, Charlie, and then carn't I paint the town red?" The author of the article is careful to say in regard to the last quotation, "The phrase has paled down to the more general sense of 'enjoying oneself,' or, perhaps, 'astonishing the natives.' "

I leave to some graduate student in English, in search of a dissertation subject, the further study of our expression, and turn to the question of the origin and development of what is now a piece

of slang. It is evident at once that the discussion involves the use of the color red as expressive of festivity. The subject is an enormous one and includes such topics as: magic, fetishism, taboo, savage customs and primitive religions—in fact, almost every field of folklore. I must in my brief space confine myself to narrower limits, and I shall try to study chiefly the use of red paint on festal occasions, although I can not avoid touching on some of the other uses of red color, as well as the origins of such uses. I shall not observe a chronological order, but sometimes work backward from a given custom.

I shall begin with the instance which led me to prepare this paper. Cicero, in a jocose letter to L. Papirius Paetus (*Fam.* ix, 16), says, "What's all this about a pilot-fish, a *denarius* (a dinner for a quarter a head), and a dish of salt fish and cheese? In my old easy-going days I put up with that sort of thing; but times are changed. . . . Yet, after all, I don't require dinners superfluous in quantity; only let what there is be first-rate in quality and recherché. . . . But if you persist in bringing me back to a dinner like your mother's, I should put up with that also. For I should like to see the man who had the face to put on the table for me what you describe, or even a polypus—looking as red as Iupiter Miniatus." That is, as red as the statue of Jupiter painted with red-lead or cinnabar.

Pliny, *Nat. Hist.*, Bk. xxxiii, cap. 36, tells us: "It is also in silver-mines that *minium* is found, a pigment held at the present day in very high estimation; and by the Romans in former times used for sacred purposes as well. Verrius enumerates certain authors, upon whose testimony we find it satisfactorily established that it was the custom upon festivals to color the face of the statue of Jupiter even with *minium*, as well as the bodies of triumphant generals; and that it was in this guise that Camillus celebrated his triumph. We find, too, that it is through the same religious motives that it is employed at the present day for coloring the unguents used at triumphal banquets, and that it is the first duty of the censors to make a contract for painting the statue with this color. For my own part," he continues, "I am quite at a loss for the origin of this usage; but it is a well-known fact that at the present day even, *minium* is in great esteem with the nations of Aethiopia, their nobles being in the habit of staining the body all over with it, and this being the color appropriated to the statues of their gods."

In a later chapter (xxxv, 44), Pliny speaks of a clay figure of Jupiter in the Capitol and says that "hence arose the custom of painting it with *minium*." How long this custom lasted I do not know, but a Christian writer of the fourth century, Arnobius

(*Adversus Nationes*, vi, 10), speaks of seeing among the gods of the Romans "those with the savage face of a lion smeared with pure *minium*." Middleton, "The Remains of Ancient Rome," I, p. 360, says the custom lasted as late as the Imperial period.

I can not dwell longer now on this particular point, but will refer my readers to J. G. Frazer's translation of "Pausanias's Description of Greece," vol. III, pp. 20–22, where other instances are given and many examples of the use of red or blood among savages.

References to this custom are found in Latin literature, as those will recall who are familiar with their Virgil and Tibullus. In the sixth Eclogue, "Silenus," two young fauns, Chromis and Mnasyllus, find Silenus sleeping in a cave, and with the assistance of the nymph Aegle extract from him a song that he has often promised them: "Falling on him, for often the old man had mocked them both with expectations of a song, they fetter him in his own garlands. Aegle joins company and reinforces their faint courage. Aegle fairest of the Naiads; and now that his eyes are open, stains his brow and temples with blood-red mulberries." Servius, the ancient commentator, says: "On account of this expression many think that red is the color of the gods, whence triumphing generals have their faces painted red and Jupiter in his chariot in the Capitol." In the tenth Eclogue, "Gallus," the friend of Virgil, is portrayed lying under a mountain rock, lost in tears and despair, while his sheep stand mournfully around him. He is visited by the shepherds, as also by Apollo, Pan and Silvanus, rustic deities, who endeavor to console him, but in vain. In the 26th verse, the poet says: "Pan god of Arcady came, whom our eyes have seen, red with blood-stained elder-berries, and vermilion." Servius says on this passage: "Pan has his face painted red on account of his likeness to the ether, the ether is Iuppiter. Whence the triumphing generals, who have all the insignia of Iuppiter, the sceptre, the palm-branches"—as Juvenal says, x, 38, in tunica Iovis—"have their faces also painted red, like the color of the ether."

The two references in Tibullus are in the first elegies of the first and second books. In one the poet depicts the charms of country life; in the other he describes the old Roman festival of the Ambarvalia. In the former he invokes various rural deities and declares "that Priapus, the ruddy guardian of the orchard, shall be placed where he can terrify away the birds by his fierce sickle"; in the second passage, in describing the festival, he says: "The husbandman, wearied with the continual labors of the plough, first sang rustic words in determinate measure, and first modulated after his repasts, on the dry oaten pipe, the airs he prepared to sing before

the adorned images of the gods. The husbandman with cheeks reddened with *minium* first led thy unfashioned chorus, O Bacchus; a he-goat, the leader of the flock, was given to him from the full fold —a notable reward.''

Whence the above mentioned customs, and why is red used as the color of festivity? It is generally conceded that the first red color was blood, and that all the festive and ceremonial uses of red are to be referred to the various meanings attached to blood, and that in the course of time, largely owing to the question of cost, red paint was substituted for blood. Instead of confusing my readers with a great mass of citations, the vice of Frazer, I shall quote almost entirely from a single remarkable article by Friedrich von Duhn entitled ''Rot und Tot'' in the *Archiv für Religionswissenschaft*, vol. ix (1906), pp. 1–24.[2]

Von Duhn begins with the contrast in German proverbs between ''red'' and ''death,'' and ''red'' and ''black.'' ''What is red must become black and dead, and what is black and dead has the longing to become red again.'' In these characteristics of primitive thought lies in a nut-shell the key to the whole funeral ritual. In the countries around the Mediterranean the receptacles for the dead are painted red on the inside, and always with cinnabar or *minium*, like the color of blood. Everywhere the effort is made to arrange the passage of the dead into the other world in as little painful a manner as possible, by making the form and contents of the grave such as to give the idea that he is in his customary surroundings. This feeling is strengthened by regular offerings and libations at the grave, and the illusion is carried still further by painting the walls of his narrow dwelling with the color, and in a certain sense, the matter of life. All this was done not from piety, sympathy or sentimentality, but to make the dead as little harmful as possible to the living, so that he shall not want to return and carry others back with him. It was this fear of the return of the dead that led to mechanical means of prevention, such as the position of the body, heavy load of earth or stones on the grave, or strong receptacles or constructions with heavy stone at entrance. Sometimes the body was mutilated—eaten—burned.

As long as the decomposition of the body was not an accomplished fact, the notion prevailed that it still possessed sensation, either inherent or that might be aroused by certain means. The dead during this period longs instinctively for life, for blood; hence the offerings for the dead with all their endlessly diversified forms

[2] Another admirable article is by Hans Berkusky, ''Zur Symbolik der Farben,'' in *Zeitschrift des Vereins für Volkskunde*, XXIII (1913), pp. 146–163; (Black, White), 250–265; (Red, 250–262). See Appendix B for résumé.

of accomplishment. Hence, at least as an ultimate reason, the red color in the inward arrangement of the grave. Even in the preparation of the body the use of red color was often indispensable. Servius (iii, 67, cf. Diels, *Sibyll. Bl.* 72) quotes an interesting passage from Varro, who says: "Women at funerals are wont to scratch their faces so that they may propitiate the gods of the under world by the sight of their blood. Whence also has been ordained the sacrifice of victims at the grave. Among the ancients even human beings were slain, but since it was costly and cruel to slay men, the custom arose of throwing over the dead a red garment."[3]

May I digress a moment here to call attention to an extraordinary survival of this custom? Before the coffin of the late Pope Leo XIIIth was closed forever, to await in a side chapel of St. Peter's his translation to the Lateran, a thin covering of crimson silk was spread over the body, which rested in a coffin lined with crimson velvet (A. Sonny, "Rote Farbe im Totenkult," *Archiv für Religionswiss.* IX, pp. 525–529).[4]

To return to classical times: the Trojans (*Aen.* vi, 221) cover the body of Misenus on his bier with his well-known red robes. "Purpureasque super vestes, velamina nota, Cojiciunt." So with Priscilla (Statius, *Silvae,* v, i, 221): "High upon a silken bier she lay, underneath a canopy of Tyrian purple." So Iphigenia was led to sacrifice in a red garment, and in India red is regarded as the color of death.[5] See also *Archiv. f. R.* xi, 406, O. Janiewitsch[6] for curious survival.

[3] Women were forbidden in the XII Tables to scratch their faces at funerals: Mulieres genas ne radunto, neve lessum (exclamations of sorrow) funeris ergo habento, Wordsworth, "Fragments of Early Latin," p. 535. Cutting of the flesh and hair was a common form of mourning, especially in the East. As connected with the worship of Adonis and otherwise leading to excess and fanaticism, it was forbidden in the Mosaic Law (Levit. xix: 27, 28, etc.), but in later times it seems to have been reintroduced. See Jeremiah xvi: 6, 7. Similarly this and other such prohibitions were not observed with any strictness at Rome. *Cf.* Propertius, III, 13, 27:

> Tu vero nudum pectus lacerata sequeris,
> Nec fueris nomen lassa vocare meum.

See passage from Servius cited above.

[4] Atlay in his Victorian Chancellors, I, p. 263, cites from Lord Brougham's Life, II, 428, an account of the funeral of Queen Caroline, wife of George IV.: "The crimson coffin slowly descended from the pier, and the barge that convoyed it bore the flag of England floating over 'Caroline of Brunswick, the murdered Queen of England,' the inscription directed by herself."

[5] To the passages just cited may be added: Statius, ii, i, 159, "The grim pyre (of Glaucias) was heaped upon a mound covered with scarlet flowers ('purpureo tristis rogus aggere crevit' "); *Thebiad,* vi, 62, "Tyrioque attollitur ostro molle supercilium." See also in Cicero, *De legg.*, ii, 59, in a corrupt copy of the XII. Tables, "extenuato igitur sumptu tribus reciniis et (tunicula ?)

I can give but a single example from savage customs. In New Zealand the remains of the chiefs are wrapped in a red cloth, placed in a coffin stained red and laid in a grave painted red, near which a red grave-stone must be erected.[7] (*Cf.* Lubbock, "Early Races of Scotland," II, 462: "Origin of Civilization," p. 309.) See Appendix A.

In many graves little pots of rouge have been found as well as sepulchral images painted red, and Von Duhn is inclined to think this indicates an effort to give the dead the appearance of life and vigor. This, he thinks, is the reason why in all parts of Europe are found remains of the dead painted red. This is accounted for in a different way by A. Sonny in the article in the *Archiv für Religionswissenschaft,* ix, 525; he thinks that the red matter found in graves is the remains of offerings to the dead, and that paint was a substitute for the more costly blood of the sacrifice. It is possible, he thinks, that the custom later extended to the painting of the bodies red, and the bones from which the flesh had been stripped.[8]

It is a short step from the uses of red mentioned above to those in connection with religious ceremonies and festivities. The liturgical use of red is an interesting subject, but one I can not dwell on now. Those who have seen a great church at home or abroad decorated for a festival will remember the profound effect produced by the crimson hangings covering the stately columns of the edifice.

I have not found many references to the academic use of red besides gowns, etc. (really liturgical), but here is an amusing one. When Sancho Panza returns from El Toboso whither his master had sent him on a mission to the lady Dulcinea, Don Quixote, on seeing him, cried:—"What cheer, friend Sancho? Am I to mark this day with a white stone or with a black?"

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vincla purpurae et decem tibicinibus tollit etiam luctum." Wordsworth's text is: "extenuato igitur sumtu tribis riciniis (relictis) et uno claro (clavo) purpurae et decem tibicinibus tollit etiam lamentationem."

[6] In some provinces of Russia the coffin is sometimes wound with red threads, sometimes a red woolen thread is laid across the body. See *Archiv f. Religionsw.*, XV, p. 313–318, Rudolf Pagenstecher, "Rache puppen aus Mexico und Verwandtes," one of the dolls is also wrapped with red thread. "In this case needles and thorns are not enough to bind the rival. The figures are wound with threads to render any defence on the part of the bewitched impossible. (Refers to Von Duhn and Janiewitsch with the suggestion that in order to make the dead harmless the coffin is wrapped with threads and only as a final allusion a red thread is laid across the corpse.)

[7] See Jervons, T. B., "An Introduction to the History of Religion," London, 1896, p. 67.

[8] For other explanations of red see Professor R. Harris, "The Red Robes of the Dioscuri" in *The Contemporary Review,* No. 557, May, 1912, pp. 657–668.

"Your worship," answered Sancho, "had better mark it with red earth, as they do the college lists, to be more plainly seen by those who look."

Watts in his translation has a note: "Those who had won the degree of doctor at the Spanish universities were signalized by a mark in red chalk placed against their names."

When I was in Salamanca, in 1910, I saw the walls of the university buildings and even of the churches covered with the names in red paint of those who, with much tribulation, had won their degrees.

Now, what is the connection of all this with the expression "painting the town red"? Are we dealing with a case of survival or of atavism? A few years ago the students of Harvard defeated the Princeton baseball team. In the celebration which followed the town of Cambridge was painted vividly red and the statue of John Harvard, in the College Yard, was decorated as brightly as the Capitoline Jove. Strange to say not a member of the faculty seemed to realize what an interesting case of survival had occurred. Quite unanimously faculty and students rose in righteous indignation and cast out those whom they regarded as offenders. One of the exiles applied for admission to Cornell, and fortunately for him I happened at the time to be the dean of the Faculty of Arts and Sciences as well as one of the founders of the American Folk-Lore Society. It is needless to say that I welcomed, in my latter capacity, one who had been engaged in so interesting a proceeding, while in my capacity as dean I felt it was perfectly safe to admit him to Cornell, especially as at that time we had no statue of Ezra Cornell to decorate after our athletic victories.

APPENDIX A

I can not refrain from citing here an example of this custom which has been embedded in a work of modern literature. I allude to Schiller's "Nadowessische Totenklage" (1797), the source of which is very interesting. Jonathan Carver, born in 1732 at Stillwater, Connecticut, undertook extensive journeys through the western part of North America in the years 1766, 1767 and 1768. The first edition of his account of these travels was published at London in 1778, and a German translation: *Reisen durch die innern Gegenden von Nord-Amerika in den Jahren 1766, 1767 und 1768, mit einer Landkarte. Aus dem Englischen. Hamburg,* 1780, 8vo. pp. xxiv, 456, fell into the hands of the great poet.

Carver, in his Chap. xv, relates how the Naudowessies (Sioux), a tribe of Indians living west of the Mississippi, treat their dead. He says (London, 1778, pp. 399, seq.):

> After the breath is departed, the body is dressed in the same attire it usually wore whilst living, his face is painted, and he is seated in an erect posture on a mat or skin placed in the middle of the hut with his weapons by his side. His relations being seated round, each harangues in turn the deceased; and if he has been a great warrior recounts his heroic actions nearly to the following purport, which in the Indian language is extremely poetical and pleasing:

"You still sit among us, brother, your person retains its usual resemblance and continues similar to ours, without any visible deficiency, except that it has lost the power of action. But whither is that breath flown, which a few hours ago sent up smoke to the Great Spirit? Why are those lips silent, that lately delivered to us expressing and pleasing language? Why are those feet motionless, that a short time ago were fleeter than the deer on younder mountains? Why useless hang those arms, that could climb the tallest tree or draw the toughest bow? Alas! every part of that frame which we lately beheld with admiration and wonder, is now become inanimate as it was three hundred winters ago. We will not, however, bemoan thee as if thou wast for ever lost to us, or that thy name would be buried in oblivion; thy soul still lives in the great Country of Spirits, with those of thy nation that are gone before thee; and though we are left behind to perpetuate thy fame, we shall one day join thee. Actuated by the respect we bore thee whilst living, we now come to tender to thee the last act of kindness it is in our power to bestow: that thy body might not lie neglected on the plain, and become a prey to the beasts of the field, or the fowls of the air. We will take care to lay it with those of thy predecessors who are gone before thee; hoping at the same time, that thy spirit will feed with their spirits, and be ready to receive ours, when we also shall arrive at the Great Country of Souls."

Note on p. 403, Carver says:

One formality in mourning for the dead among the Naudowessies is very different from any mode I observed in the other nations through which I passed. The men, to show how great their sorrow is, pierce the flesh of their arms, above the elbow, with arrows, the scars of which I could perceive on those of every rank, in a greater or less degree; and the women cut and gash their legs with sharp broken flints, till the blood flows very plentifully.

Schiller's poem has been translated by Bulwer and Sir John Herschel. Here is the last stanza in the two versions:

The paints that deck the dead bestow—
Yes, place them in his hand—
That red the kingly shade may glow
Amid the spirit-land.

The scalping-knife beside him lay,
With paints of gorgeous dye,
That in the land of souls his form
May shine triumphantly.

The German is:

Farben auch, den Leib zu' malen,
Steckt ihm in die Hand,
Dass er röthlich möge strahlen
In der Seelen Land.

APPENDIX B

Résumé of Hans Berkusky's article: "Zur Symbolik der Farben" in *Zeitschrift des Vereins für Volkskunde,* xxiii (1913), pp. 250–262.

If white is the color of death, so red, the brightest of all colors, is a symbol of life, for red is the blood, and blood and vigor are for primitive

man almost identical ideas. The custom of drinking the blood of slain enemies or of sacrificed animals or men to strengthen one's own energy is widespread to-day among numerous savage tribes; a wounded Somali (Ph. Paulitschke, *Ethnographie Nordostafrikas*, Berlin, 1893, p. 186) drinks his own blood with the notion that he can thus take again within himself the strength that is escaping with his blood.

Among the various means by which primitive man seeks to increase his vital energy, the drinking of blood is in all probability the earliest. The changes and development which this earliest form has undergone in the course of time may perhaps be distinguished as follows: the drinking of blood—the painting, anointing or sprinkling with blood or wrapping the sick in the bloody skin of a newly slaughtered animal—the painting of the body red or the tatooing of red figures, to which magic power is ascribed—and finally the wearing of red garments or red amulets.

That the red color, with which numerous primitive peoples paint their bodies, originally at least is to be regarded as a substitute for blood, follows from the fact that until the very present time by the side of the painting of the body with red color, perhaps the earlier form, the smearing of the body with blood has been preserved (Samter, *Geburt, Hochzeit und Tod*, p. 187, *Familienfeste*, p. 53).

Berkusky then takes up each of these topics and gives numerous references under each. I must omit until p. 253.

If primitive peoples paint their bodies red on festal occasions it probably arises from the fact that such festivals make an unusual demand upon their strength. . . . The original significance of this custom—to strengthen the vital energy, in many cases no longer clearly appears. The red color of the body is finally only a festal ornament, and because the primitive man is inclined to make the most of his outward appearance, he paints his body red.

The Dead (p. 254). The living are painted red, the dead should not be deprived of the ornament he has had when alive. In many cases, however, the red color is not an ornament but a substitute for the blood of animals slaughtered in honor of the dead. . . . The dead must strain all his energies to escape the numerous dangers, which threaten him on his journey to the other world, the dead are therefore painted red in order that they may overcome victoriously all calamities and trials.

Then follow references to painting parts of the body red, pp. 254, 255. As the bones of the dead, so other objects endowed with magic powers are painted red: statue of Jupiter, stones, idols, etc.

While (p. 256) the almost naked man applied the red color directly to his skin, in the course of time as the need of more clothing was felt, this custom was replaced by wearing red clothing and red amulets. These increased, it was supposed, the vigor of the body and its resistance to harmful influences of all kinds.

Sympathetic remedies, p. 257; amulets against the Evil Eye, etc., p. 258; Red in marriage customs, pp. 259–260; Red a lucky color, p. 260; Red animals in sacrifice, p. 261.

Finally, the custom is referred to of wrapping the dead in red garments or burying them in red coffins. This is done partly for the same reason as painting the dead red, and partly also to keep the dead in his grave; as red is a preventive against evil spirits so the dead will be hindered by the red color from leaving his grave and disturbing the living. (Berkusky gives many references to this custom in various lands).

A considerable number of references may be found in Henry Fairfield Osborn's "The Men of the Old Stone Age." New York, C. Scribner's Sons, 1916, pp. 290, 304, 305, 337, 379, 380, 476–79. See W. K. Morehead, "The Red Paint People of Maine," *American Anthropologist*, N. S. vol. xv, pp. 33–47, and Holmes (W. H.) Anniversary Volume, Washington, 1916.

APPENDIX C

Since writing the above paper a new explanation of the ceremonial use of red has been given by Rendel Harris in his *Boanerges*, Cambridge University, University Press, 1913, as well as in some previous essays, notably "The Red Robes of the Dioscuri" in the *Contemporary Review*, May, 1912. Mr. Harris sees in the red color the representation of lightning and says, op. cit. p. 31, "It has not, however, been as commonly recognized that the reason why the robes are red lies in the fact that the Twins are personifications of the lightning being either Sons of Zeus or Sons of Thunder, or Children of the Sky, or whatever other title may express their superhuman affinities.

Suppose then we start from the statement that red is the proper color for the lightning, and illustrate that statement by reference:

1. To the color ascribed to the Thunder-Bird, who is the zoomorphic representative of thunder and lightning.
2. To the color ascribed to the anthropomorphic representation of the deity who controls the thunder.
3. To the color worn by the priests and human representatives of the aforesaid deity.

If all these developments of the idea of thunder and lightning tell the same story of color, we shall have little doubt as to the meaning of that color when it appears in the raiment of the Heavenly Twins.

Earlier in p. 3, Harris says: We shall see by-and-by, when we examine into the cult of the Heavenly Twins more closely, that in almost every case in which the Twins are represented, in art, in worship, by an attached priesthood, or by appropriate sacrifices, one color dominates the representations, the red color of the lightning.

P. 41. "But it is not only Thor that makes the connection between the earlier zoomorphs of the thunder and the red color of the thunder. Jupiter Capitolinus himself was formerly a red-painted image; so that there could be no mistake in saying that he was, par excellence, the Thunder. He was fulminate, as far as color could make him, and strangely like the Northern Thor." . . . It has been pointed out, for example, that, in the old times, a successful Roman general, to whom a triumph was granted, was considered as an actual impersonation of Jupiter, and to fulfil that dramatic action he was painted red (Pliny, Nat. Hist. xxxiii, 36).

See p. 91 for absurd explanations of the barber's pole.[9]

See pp. 396, 397, for red color of "bull-roarer," etc.

[9] "But the explanation of the pole by blood and bandages has an unnatural look about it. Perhaps if we examine more closely into the history of surgery we may see the matter more clearly. Who are the patron saints of surgery? The answer of the mediaeval world will be at once, Cosmas and Damian, the saints who healed without taking fee, the Christian heirs of Aesculapius and of the Heavenly Twins. The barber's pole is, then, the sign of Cosmas and Damian: but Cosmas and Damian are the Heavenly Twins: then the red and white stripes are the sign of the Sons of Thunder. The induction is too rapid to be altogether satisfactory."

THE ORIGIN, NATURE AND INFLUENCE OF RELATIVITY[1]

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IV. The Experimental Tests of Relativity

It would be impossible to limit speculation about physical laws by the demand that a theory must apply in all respects. The vortex theory of the atom has always been considered to be of great interest, although never applied successfully. A theory of major importance will have many applications, of course, and may suggest the way to new discoveries. Thus the Newtonian formulation of gravitational law led to the discovery of the planet Neptune through the observed irregularities in the motion of Uranus.

The theories of relativity are unquestionably of very high speculative interest. The extent to which they will be found in harmony with nature is not yet fully disclosed. If a just estimate of them is desired, it is necessary to adopt the spirit of impartial inquiry in dealing with the relevant experimental facts. In this critical spirit it may be asked whether or not there is some common ground which furnishes a satisfactory basis for consideration of the questions at issue. It has been pointed out previously that there is an extensive basis of this kind.

In the first place, it is agreed that the measurement of time by more or less arbitrary means is possible so that events can be classified by means of their time of happening, while the events happening at a particular time can be spatially classified in various ways, this last classification requiring three space measurements. An event, such as the collision of two atoms, is the elemental physical reality specified by these four measurements, and the totality of events constitutes the substratum of the physical universe now called space-time.

Furthermore, it is granted that material objects can be identified, and followed in time. Any such object occupies a definite part of space at any time. It is assumed that there is the possibility of continuing this process of identification of objects down to the point particle.

Solids, liquids and gases may be subdivided. However, chemists, in their consideration of the various kinds of matter, have been led to the conclusion that they were made up of indivisible atoms of a definite type for each chemical element. This conception has proved of great simplifying power. More recent advances make it plain

[1] Lowell lectures.

that electricity also is atomic. Magnetism is held to be merely electricity in circulatory motion. These elementary units of matter and electricity have spatial extension. Besides these, there is only space-time free from matter and electricity.

Let us turn now to the consideration of nearly empty space-time and review the generally accepted facts briefly. For the moment let us adopt the notion that a clock is available at each particle to measure the lapse of time there, and that light disturbances can be observed which originate at other similar particles. If it is assumed that such a space-time is alike in all its parts, it follows conclusively that with any such particle may be correlated an optical system of space and time, with reference to which all other particles will travel at a constant velocity in a straight line, while light travels with one and the same velocity under all circumstances.[2] The conviction that space-time, remote from material bodies, is homogeneous and of one nature throughout, has the same reasonableness as the conviction that all parts of a plane are alike. The experimental method of spatio-temporal measurement employed may be based upon a process of light signaling between three particles relatively at rest, and the use of a clock at one of them. The space obtained by such methods will be Euclidean.

Here is a considerable basis of facts about which there is no dispute.

In the spaces and times attached to small particles in empty space-time, there may happen to exist a unique one of simplest type from a physical point of view. This will be the space and time of a set of particles "at rest." It will then be legitimate to call such a space and time *absolute*, and so we arrive at classical physics. The only alternative is that all the spaces and times are on exactly one and the same physical footing. This hypothesis yields the special theory of relativity. Which of these alternatives really holds?

The understanding of the situation turns upon the highly difficult and interesting concept of the clock. The ordinary pendulum clock itself does not conform to what is meant; such a pendulum clock and the earth together more nearly constitute a clock in the technical sense. This particular type of gravitational clock would have to be of small dimensions for purposes of exact temporal measurement in nearly empty space-time. A pocket watch would be more nearly a clock of the desired type. Even for this elastic clock, uniform conditions of operation would be essential. There would be required constant pressure and temperature, and freedom from gravitational, electric, magnetic or rotational stress. A body like

[2] This is true because the light-second is defined as the unit of distance.

the earth in rotation furnishes a type of rotational clock. In fact, as soon as phenomena are regarded from the proper point of view, it appears that more or less exact clocks are omnipresent in nature.

Now the statement that the universe of events is four-dimensional has no real meaning unless it is possible to identify events of a specific type *T* exactly. It has been assumed that particles are identifiable. The events at a particle are evidently arranged in a time order. Now if two events *A* and *B* of the particular type *T* happen at a particle, an interval between the two events is set off. An indefinite recurrence of such events measures the time order at this particle, and similarly at other particles, and thus the comparison of time intervals elapsing at different particles becomes possible. In other words, such a sequence as *A*, *B* functions as a clock of type *T*. Thus it seems clear that the mere possibility of spatio-temporal measurement involves something of the notion of the clock at any particle.

However, in both the old and new theories, the physical reality of the local interval of time is conceded. Hence it is clear there must exist appropriate ideal types of local clocks with which this quantity can be measured. Of course the ideal clocks used must run at the same time when together, and even when relatively at rest. There will then be physical significance in the relations between the spaces and times of various particles.

If two such clocks are separated and later brought into coincidence, it does not follow that the same length of time has necessarily elapsed on both clocks. To assume the contrary is to require the existence of absolute time.

When there is more than one kind of clock, as *M* and *N*, so that if a clock *M* has the same rate as *N* at one particle, it need not have when brought again into coincidence with *N* at some other particle in relative motion with respect to the first, then a difficulty arises as to whether *M* or *N* is the selected ideal type of clock. Thus, a vibrating sodium atom may be called a clock *M;* an oscillating spring may be taken as a clock *N*. If the interrelations of the various spaces and times are to have genuine physical significance, it is impossible to evade the demand that these and other kinds of clocks shall keep the same time at every particle, *unless one selects arbitrarily a particular kind of clock as ideal.*

If there is a unique physical reality, corresponding to our naïve feeling of duration at any particle in empty space, it is reasonable to suppose that all clocks will measure that duration. Nevertheless, the classical physics of Newton and Faraday has more than one type of clock. Thus an oscillating spring yields an elastic clock in the

meaning of our definition. Likewise, a pair of mirrors mounted at the ends of a rod, between which light is flashing back and forth, forms a 'light clock.' Either of these possesses the fundamental properties required. Now will these two clocks keep the same time? The answer is in the negative, since, according to the formulation of the laws of motion, only the elastic clock will measure *real* intervals of time, while the light clock will go more slowly with respect to the elastic clock, the larger its absolute velocity. But why should either be preferred? It is difficult to find any genuine reason for the choice made.

It will be seen from this very simple example that the behavior of these two types of clocks would enable us to single out the absolute space of Newton and Faraday; it will be that space in which the light clock at rest runs most rapidly relatively to the elastic clock at rest. The corresponding time measurement can then be called absolute time. An absolute system of reference is determined.

This is not accidental. When relativity does not exist, all particles in empty space are not on a physical parity. The distinction between them will affect the types of clocks in various ways, and thus their relative rates at different particles.

The test of relativity is thus seen to be that small local clocks of any type will run at the same rate whenever and wherever brought together at a particle in empty space, provided that their rates have once been synchronized by proper choice of a unit of time, say the second.

The test of the alternative possibility of absolute time and space is that at least two kinds of clocks can be found in nature.

These will be related to one another as the elastic and light clock cited above are in the space-time of Newton and Faraday.

With the phrasing of the distinction in such simple terms, the immediate consideration of the facts is in order.

Here a remark must be interpolated in fairness to the classical theory. The possibility of accepting it lies in the fact that bodies found in nature have a small *absolute* velocity, *i.e.*, that the space attached to the sun or any star is very nearly the absolute space. If this were not the case, the fact would be revealed in various ways, for example, by the asymmetric behavior of the spectra of the stars. Now when absolute velocities are small, it is not difficult to prove that relativity of motion will be simulated to a considerable extent. Witness the aberration of light and the Doppler effect, as explained on the old basis. These turn out to depend, as far as the principal effect to be observed is concerned, on the relative velocities only.

Hence, when we are dealing with bodies moving at low relative velocities, it is necessary to achieve a high order of accuracy in any

crucial experiment. Since the ratio of stellar velocities to the velocity of light is of the order of one to one thousand, the method will have to possess an accuracy of one part in one million. There are not many experiments in which such a degree of accuracy can be obtained, but they are of great interest.

The equations of Maxwell have always been accepted as applicable to electromagnetic waves in empty space-time, where the space and time are obtained by ordinary means of measurement. The velocity of these waves can be determined theoretically and experimentally; it is independent of the frequency of the exciting electric oscillator, and is the same as the velocity of light. This last fact, and the very great parallelism between the optical and electrical behavior of the elements, extending to the equality of corresponding optical and electrical constants, indicate that the light wave is merely an electromagnetic wave of very high frequency. There must then be something in the characteristic atomic units from which these light waves are derived which is of the nature of an oscillator or atomic clock.

The wave character of light is conclusively demonstrated by the phenomenon of interference, according to which two beams of light of the same frequency may interfere to yield darkness. By this means the most exact measurements of length can be made.

In the celebrated Michelson-Morley experiment of 1887, a beam of light was divided, sent along two bars and then brought back to interference. If there had been any variation in the relative rate of the atomic clock from which the beam of the light came, and the light clock formed by the beam and the bars, with the varying velocity of the earth, there would have resulted a slight shift of the interference bands. One hundredth of the shift expected under the classical theory would have been within the reach of observation, but none was found.

The meaning of the experiment is that the light clock and the atomic clock run at the same rate. Another way of stating the meaning of the experiment is to say that the shape of any undisturbed body will always be the same in the reference space and time which belongs to it, as measured by light signaling and the atomic clock, or by the measuring stick. From a logical point of view the experiment is corroborative but not crucial.

Another kind of clock can be defined as follows: Consider a tube filled with water and not rotating, and a beam of light which traverses the tube. It will take a certain interval of time for the beam to traverse the tube of water, as measured in the attached space and time. This will then yield a new kind of clock.

The situation may be looked at as follows: If there is an absolute space, and the tube is not at rest in it, then in the space attached

to the tube, the absolute space or ether will appear to be moving through the tube in some particular direction. A beam of light which travels in the same general direction as the ether would seem likely to have a different velocity than when sent out in the opposite direction, and this difference in velocity ought to be measurable, provided that the ether is in any sense a medium as the water is. In other words, the new kind of clock would be expected to yield a measure of time, differing according to the absolute velocity of the water.

Here again no effect of the anticipated kind revealed itself under most careful duplication of the Fizeau experiment.

It is generally held that the Michelson-Morley experiment takes a central position in the experimental testing of relativity. Hence, it is of importance to see how it has been interpreted by those who hold to the old theory of space and time. The hypothesis of ether drift has been advanced as an explanation, according to which the earth carries the ether in its vicinity along with it. Since the original experiments were carried out in a building, such a drift was felt to be especially likely to cause the negative result.

The logical difficulties involved in the concept of ether drift can not be too strongly emphasized. On any previous theory the ether was a particular absolute space singled out by its property that light traveled in it with the same velocity in all directions. There was now tacitly assumed to be some further underlying reference frame—the true space—with no definite physical properties.

Nevertheless, it was of great interest to repeat the experiment, preferably upon a high mountain, as D. C. Miller did at Mount Wilson in 1921. His measurements indicated a shift in the bands of about one fifth that required by the classical theory. A second effect, not expected on any theory, was also found. After elimination of direct disturbances from ordinary heating and magnetic action, these two effects remained. However, the error due to radiant heat requires further investigation and seems likely to explain the two indicated small shifts observed.

Some physicists and astronomers, in opposing the new theories, are willing to accept the Lorentz contraction hypothesis in the interpretation of the same experiment. This is particularly difficult to understand because Lorentz accepts the theory of relativity as the proper expression of his own hypothesis. The reason for the essential equivalence was presented earlier.

The fact is that Einstein has provided the reasonable way out of a dilemma in which physics was placed by various experiments like those referred to above. Without the readjustment of the

concepts of space and time, to the exceedingly slight extent contemplated in the special theory, theoretical physics would be in a difficult position to-day.

The electromagnetic equations of Maxwell have a complete relativistic form to begin with, while the equations of classical mechanics can be modified slightly to correspond. The behavior of an electrified particle at velocities comparable to that of light under electromagnetic forces is found experimentally to follow the law thus obtained. It can be said that the known facts of mechanics and electromagnetism are then adequately accounted for. When this is not done, the attempt to explain the facts seems to lead step by step to complete relativistic form. The obvious inference is that the easiest manner in which to grasp the physical situation is to assume the principle of relativity at the outset. If we refuse to do so, the difficulties seem endless. The immense usefulness of this spatio-temporal principle of relativity has been pointed out previously.

The argument of convenience thus becomes paramount. It is the same consideration as that which established the Copernican theory as against the Ptolemaic.

Moreover, no mean philosophical importance attaches to the fact that, if absolute space and time exist, then the interval of local time is devoid of a unique physical meaning. The theory of relativity has the unquestionable superiority that for it local time has physical reality.

The notion that the interval of local time is a basic reality may be looked upon as the guiding principle of the general theory of relativity to whose experimental verification we turn next. Its successes afford substantiation of an important kind for the special theory.

The interval of local time between events at a particle suggests the distance between points of a line to the mathematical mind. Minkowski pointed out that the space-time of the special theory was analogous to a flat surface. According to the general theory of relativity, when matter is present in large quantities the space-time is analogous to a curved surface. It is such a curvature which is held to account for gravitation. On the basis of the hypotheses that the well-known purely mathematical measure of curvature indicated the density of matter and energy, and that empty space-time was as flat as possible, Einstein obtained a definite theory which explained the observed laws of gravitation. The new gravitational law was as uniquely determined as that of Newton. Consequently, the tests of the theory by means of the slight predicted differences may be regarded as especially conclusive.

The variations from the older theory were declared by him to be within the reach of observation in three cases, all of them depending upon the large mass of the sun as their cause.

Firstly, there must be a rotation of the line of symmetry of the orbits of the planets in their revolution around the sun, by an amount in excess of that demanded by the Newtonian theory. This additional effect is largest in the case of the planet Mercury. Fortunately, the angular advance of the perihelion of Mercury had been measured with accuracy. Before the theory of relativity was thought of, there had been found an advance, beyond that expected on the Newtonian basis, of about forty seconds a century. This unexplained fact had been held to be the one real difficulty in the way of a complete success of the Newtonian theory as applied to the planets.

The Einstein theory indicated an advance of the right amount for the perihelion of Mercury, and advances of the right order of magnitude for the other planets. These are of minor importance compared to that of Mercury in the opinion of astronomers generally. When it is borne in mind that, if the advance had been of any other amount, it would not have been possible to readjust the Einstein theory to suit it, the importance of this verification is obvious.

It is possible to account for the same advance by properly distributing fine particles of matter about the sun. The most competent opinion is that there is no evidence for such matter in the amount required.

The second effect to which the theory led had to do with a hitherto unobserved phenomenon, namely the apparent bending of star light near the sun. The abandoned corpuscular theory of light of Newton led to the idea that bending might occur, due to the gravitational attraction of the corpuscles by the sun. The amount to be expected on the Newtonian basis is eighty-seven seconds. Einstein arrived at the same quantitative result by a different method in 1911. The paper of 1911 was interesting, as the forerunner of the paper on general relativity of 1915. According to the general theory, the amount of deflection to be expected is nearly double that predicted on the Newtonian basis.

In order to test the prediction, English astronomers made special expeditions to observe the total solar eclipse of May 29, 1919, and found evidence of a bending of light of about the amount indicated. The measurements require the utmost skill. The observations agreed with the Einstein theory within the limits of error (about 20 per cent.), and were held to constitute another definite confirmation of the theory. Nevertheless, it was extremely desirable that further observations should be made in order that the results be definitively established.

The first occasion for so doing was furnished by the solar eclipse of September 21, 1922. An American expedition under the direction of W. W. Campbell was successful in obtaining an excellent set of photographic plates. The plates showed a radial displacement of the star images of the magnitude demanded by the Einstein theory. The mean value from four plates gave 1.72″ as against Einstein's predicted value of 1.74″. The probable error of the plates was only .11″. This initial result was in extraordinary agreement with the theory.

The notion has been advanced that the gaseous matter which exists in the neighborhood of the sun may have caused refraction of the star light. However, our knowledge of the sun's outer neighborhood is sufficient to indicate that this is an insufficient explanation.

The third effect to be expected according to Einstein was a shift of the solar spectral lines of any element toward the red end of the spectrum, as compared with a terrestrial spectrum. This is exceedingly difficult to detect, although the general consensus of opinion among those who have investigated it, has been that the shift toward the red does exist. The latest announcement by St. John, made on the basis of new knowledge concerning the solar envelope, is favorable to the theory. It is "that three major causes are at work in producing the regular differences between solar and terrestrial wave lengths and that it is possible to disentangle their effects; namely, the slowing of the atomic clock in the sun to the amount predicted by the general theory of relativity, radial velocities of moderate cosmic magnitudes and of probable directions, and differential scattering in the longer paths traversed by the light coming from the edge of the sun."

All things considered, the experimental facts bear out the new theories. The results point toward the physical uniqueness and reality of the local interval of time but not of absolute time, the relativity of physical law to any undisturbed particle in empty space, and gravitational law as merely the cosmic result of the direct conditioning of space-time by the presence of matter. These conclusions are of major importance for physics.

THE EARLY HISTORY OF TERRESTRIAL MAGNETISM IN THE UNITED STATES WITH SPECIAL REFERENCE TO THE WORK OF DR. JOHN LOCKE OF CINCINNATI[1]

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THE period centering about 1840 was remarkable in our country for the number of able and zealous investigators whose devoted labors enriched science in various fields—notably in astronomy and the earth's physics. And the city of Cincinnati has the honor of having numbered among its citizens two of the most distinguished men of science of that period—Ormsby M. Mitchell, the founder of the Cincinnati Observatory, and John Locke, one of the foremost pioneers in terrestrial magnetism, whose studies in that and related subjects won him distinction both at home and abroad.

Dr. Rufus has told us of the leading part taken by Cincinnati and Mitchell in the inauguration of astronomical work in this country. Dr. John Locke, of whom it is my privilege to speak especially, likewise contributed notably to the advancement of American astronomical science by his invention in 1848 of what he first called the "Automatic Clock Register," but later the "Chronograph," the term now generally in use. Thanks to the interest shown in this invention by Lieutenant Maury, the United States Congress was induced to contribute $10,000 for the perfection and construction of a chronograph for the National, now known as the Naval Observatory.

Through the kindness of one of Dr. John Locke's sons, the late Colonel Joseph Morris Locke, whose acquaintance I had the privilege of making when I was a resident of Cincinnati, I was enabled to see many of the scientific instruments and books used by his father, and to look over his note-books and papers. I might mention in this connection that Colonel Locke was the inventor of the Locke level, well known to engineers. He died in Washington in 1917.

Professor John Locke, M.D., was born in Lempster, New Hamp-

[1] Presented before the History of Science Section of the American Association for the Advancement of Science, Cincinnati, December 29, 1923.

shire, February 19, 1792. He was a descendant of William Locke, who sailed from London, England, in the ship *Planter*, April, 1635, for the Massachusetts Colony, and in line of descent from whom was Samuel B. Locke, president of Harvard University. Collateral branches furnished professors to Dartmouth College and other schools of learning.

His grandfather, father and brother had a fine reputation in New England as expert engineers and millwrights, or hydraulic engineers, as they would now be called. The family had for a time no settled home, but moved about from place to place wherever the father's business called him. They finally settled at Bethel, on the Androscoggin River, in Maine.

His father had a very good private library for those days, which was a great help and incentive to his son. When the youth had exhausted all local means of obtaining an education, he desired to carry on his studies elsewhere. This desire his father opposed, as he wished him to take up his own profession of millwright. Locke was thus obliged to continue unaided his efforts to obtain an education. For a while he was an assistant in Professor Silliman's laboratory at Yale. Later, he was curator of botany in Harvard. In 1818 he was appointed assistant surgeon in the United States navy. In 1819 he graduated in medicine at Yale College.

In 1821 he went to Kentucky and organized an "academy for females" at Lexington. The following year he removed to Cincinnati where he established the "Cincinnati Female Academy." In 1825 he married a favorite niece of the late Nicholas Longworth of Cincinnati. Ten children were born to them, only one of whom is still living—a daughter. In 1835 he was appointed professor of chemistry and pharmacy in the Medical College of Ohio, which chair he occupied with signal success for eighteen years.

In 1837 Dr. Locke visited Europe, where he was cordially received by scientific men. On his return to this country, he was connected for a time with the first geological survey of Ohio. In 1839 he was appointed to take part in the United States geological exploration of the mineral lands of Iowa, Wisconsin and Illinois. At Philadelphia, April, 1840, in connection with others, he organized the American Association of Geologists and Naturalists, and presided at many of its meetings. This association, by gradually incorporating other branches of science, developed into the present American Association for the Advancement of Science.

From 1838 to 1848 Dr. Locke devoted a great deal of labor to perfecting a connected survey of the magnetic dip and intensity of the northern portion of this country. In recognition of his labors in this connection, the British government, at the suggestion of the most distinguished British magnetician of that time, Sabine, pre-

sented him with a magnetometer and theodolite by Meyerstein of Göttingen. (It is believed that these instruments are among those presented by Lieutenant-Colonel Morris E. Locke to the Virginia Military Institute, of which he is a graduate.)

Dr. Locke resigned his position in the Ohio Medical College in 1853. The following year he moved to Lebanon, Ohio, but returned to Cincinnati in 1855, much broken in health. He died on July 10, 1856, at the age of sixty-four years. The scientific instruments used by Dr. Locke in his teaching and investigational work have been dispersed among the following possessors: Mr. F. G. Hunt, a former Cincinnatian, now of Washington, and a friend of the late Colonel Joseph M. Locke; Lieutenant-Colonel Morris E. Locke, a grandson of Dr. John Locke; the Ohio Mechanics Institute; and the Virginia Military Institute.

Dr. Locke made notable additions to our knowledge in various sciences. His unselfish devotion and many valuable contributions to the science of terrestrial magnetism certainly deserves more than the passing notice we can here give them. His investigations and magnetic surveys from 1838 to 1848 extended from the southern part of Kentucky to the northern side of Lake Superior, and from the state of Maine to some distance beyond the Mississippi. They were conducted almost entirely at private expense and with an enthusiasm and zeal worthy of the cause. His observations were the first to give indication of the situation of the American focus of greatest magnetic intensity, his results being verified by the later investigations of Lefroy. His excellent investigation of local deflections of the magnetic force, as exhibited notably at the Palisades of the Hudson, constitute a valuable contribution to our knowledge of the subject. It is possible that he may have the honor of having made the first absolute (or even differential) determination of the magnetic intensity.

He proposed to make Cincinnati the base of reference of a magnetic survey of the United States, and calling the value of the earth's horizontal intensity at Cincinnati unity, he determined the horizontal intensity in terms of this unit at stations in the United States, Canada and Europe.

All honor to the British government and Colonel Sabine that, when Dr. Locke's appeal for aid from American societies then in existence could not be responded to, they saw their way clear towards supplying him with the desired instruments, and thus, by their recognition of the value of his labors, gave him the stimulus and encouragement so desirable to every true investigator of nature's secrets!

SCIENCE TEACHING IN SOME EUROPEAN SCHOOLS

By Dr. ELLIOT R. DOWNING
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It was the good fortune of the writer to spend seven months in Europe in 1922 and 1923 during which time many schools were visited in order primarily to study the teaching of science. Most of the time was spent in France, for it seemed best to settle down and live among the schools of one country to understand them reasonably well, then to visit those of other countries for comparison, rather than take a hasty and necessarily superficial survey of the schools of many lands. This policy was early justified, for it was found necessary to discard most of the information gathered during the first month because the terms used in conversations with schoolmen carried such different meanings to them and to myself. Thus, "science" there includes mathematics. Inquiry was made concerning "courses of study," but when such were obtained they proved to be syllabi of particular subjects. The terms "elementary school" and "primary school," used interchangeably in this country, signify quite unlike things over there. The French schoolman uses the term "lecture" but means thereby a reading, while he uses the term "conference" with the significance of our word lecture. You do not visit a class; you assist at a class. So it was necessary, in all inquiries and discussions, to make sure that each understood the other's educational terminology. One might gather much misinformation by a hasty survey of European schools.

France is divided into fifteen districts for the administration of its academic school system. The administrative officer of each district is the rector (we should say president) of a national university; one such university is located in each district. The minister of public instruction is the director of the whole system. These districts are not coincident with the present political divisions, which are the eighty-nine departments, nor do they coincide with the old provinces that still hold over locally as designations of portions of the country. There are then fifteen national universities. Beginning with the University of Montpellier on the Mediterranean coast and swinging about Paris as a center in a clock-wise direction there are, in addition to these two, universities at Toulouse, Bordeaux, Poitiers, Rennes, Caen, Lille, Nancy, Dijon, Besancon Cleremont, Lyons, Grenoble, Marseilles.

It is evident that the rector of a university can not, in addition to university administration, be familiar with the details of a national school system or even with those of one district. So the real administrators of the normal, secondary and elementary school systems are secretaries to the several rectors, and these secretaries are chosen for their knowledge of the affairs of such schools.

While the academic school system is administered as a unit that does not mean that the whole French school system is so administered. Quite the contrary is true. Commercial schools are under the direction of the minister of commerce, agricultural schools are administered by the minister of agriculture, schools of diplomacy by the minister of foreign affairs, technical schools by the minister of labor, etc.

The French academic system now in vogue consists of free elementary schools, pay lycées and colleges, normal schools and universities. The elementary school receives children as young as three years of age and gives them eight years of training, a possible three years of kindergarten, and five of elementary work which is normally completed at ten or eleven years of age. The elementary schools are practically all in towns and cities for there is no country population living on the farms. Our "little red schoolhouse" has no counterpart on the continent. The people, even the farmhands, live in villages on the great estates.

The lycées were originally founded and maintained by the cities. Then the smaller communities demanded schools of similar grade, and the state established and largely maintained the colleges in the smaller towns. Now this distinction in method of maintenance has largely disappeared. One still finds, however, that the secondary school of the city is usually a lycée, that of the smaller community a college. In both there is a seven-year course of study that leads to the bachelor's degree, which is achieved at the age of seventeen customarily.

As a matter of fact one finds the French lad of well-to-do parents going to the pay lycée or college from the very first, because something of a social stigma attaches to attendance at the elementary school where the children of the poor receive free instruction. The Frenchman of professional rank, or even the prosperous mechanic feels quite insulted if you ask him if his children attend the elementary school. So, very early in their history the lycées and colleges tacked on below their regular course an eight-year "primary" course, the counterpart of the "elementary school" course, except that pupils must pay tuition for it. The French boy usually, therefore, receives his B. A. from the same school which he entered as a kindergartner.

The schools for boys and girls are quite separate, though in a few communities it is customary to instruct them together in the kindergarten. In the smaller communities the boys' school and the girls' school may be under a common roof, but there is an unbroken wall of partition between them and the playgrounds are similarly separated. The teachers in the boys' schools are men. Since the war the girls' lycées and primary schools are taught quite commonly by women. The course of study in the girls' lycée is quite different from that of the boys' lycée and does not result in a bachelor's degree. If the girl desires to take such a degree in order to go on to the university, she must in addition to the regular course of the girls' school take several other subjects and prepare by tutoring for the final examinations that boys regularly take.

In the elementary and primary schools about one hour a week is, according to the program of studies, devoted to object lessons out of a total of twenty hours of instruction. The prescribed work is, for the first year, acquaintance with such simple things as direction, time, seasonal changes, the differences between minerals, animals and plants; for the second and third years the occupations and products that touch daily life, such as that of the miner and coal or iron, the vineyardist, grapes and wines. The fourth year is devoted to the common animals and plants of field, forest and garden that are of economic importance, and the fifth to the materials used in construction together with some elementary physical geography.

This material is presented in talks by the teacher or in a series of small books used as readers. Since it is in the course of study which is prescribed uniformly for all schools by the central authority, the science work is given, but as a rule it is perfunctory and formal. The children are supposed to get the necessary background of experience for themselves. There are of course occasional teachers who are sufficiently enthusiastic to bring nature materials into the school for actual study at first hand, or even to take pupils out of doors for such study outside of school hours, but they are the exceptions. Pretty much the same sort of work is prescribed in the French cantons of Switzerland, and the work is done in about the same way. In the English schools object lessons are not a specified part of the work of the corresponding grades, though they may be given. They are given when some school is sufficiently interested to put them into its course and get the approval of the authorities for such action, and in some schools nature work is given very well. There is an English Nature Study Society corresponding to our American Nature Study Society that undertakes to encourage such instruction in the schools and that in the interest of such work publishes the equivalent of our *Nature Study Review*.

On entering the lycée or college the French pupil must decide whether he will pursue the classical course or the scientific. At the beginning of the fifth year of the lycée these courses split again, the classical into the Latin-Greek and the Latin-Modern Language, the scientific into the Science-Latin or the Science-Modern Language. This subdivision is not maintained in the last or seventh year of the lycée, but the classical group of pupils is then known as the philosophical, the scientific as the mathematical group. The work in science may be described for the classical and scientific courses, for there is no variation in the subject-matter presented in the latter when it splits in the fifth and sixth years, and but slight differences between the Latin-Greek and the Latin-Modern Language courses.

Classical students have one hour per week in zoology through the school year, the first year of the lycée (corresponding in age of pupils to our sixth grade), one hour the second year in botany, one the third in geology, no science the fourth year, one hour of physics and chemistry combined and one of geology (reduced to twelve lectures for the Latin-Greek students) in the fifth year, one hour of physics the sixth year, two hours of natural science and three divided between physics and chemistry in the seventh year. In addition the Latin-Greek students have twelve lectures in hygiene in this year. This totals eleven year-hours of science out of a total of 172 year-hours of work in the seven years, or nearly 6.5 per cent. Even the classical students can not complete their lycée or college work without some considerable contact in primary and secondary school with the sciences.

Scientific students have two hours of zoology per week during the first year, two hours divided between botany and geology in the second year, two hours divided between physics and chemistry in the third year, one hour of zoology and two of physics and chemistry in the fourth year, five hours of physics and chemistry and one hour of geology in the fifth year, five hours of physics and chemistry in the sixth year, seven hours of physics and chemistry and two of natural science in the seventh year. This totals 29 hours out of a total of 178 year-hours of work or 16.3 per cent. Notice that of the 29 hours, the biological sciences are apportioned only four hours, while physics and chemistry have, between them, 21. Note also that aside from the fact that physics and chemistry run parallel, the science subjects as a rule come in successive years. If we should attempt to express the equivalent of the French science instruction in the lycées in terms of the American system for pupils of corresponding ages it would mean that pupils would receive in grades six to twelve inclusive a minimum of a year and a half of

science-instruction five times a week and a maximum of four years.

The science courses in French universities are so like corresponding courses in American universities that, barring the difference in language, one would hardly know whether he were in a French or American institution. There is this very marked difference, however, that the courses that may be offered are prescribed by the central authority, and the content of them is similarly determined in considerable detail. So that the courses offered in any subject in different universities are quite exactly replicas of one another. The same thing holds true for lycées and primary schools. The work in one city is like the corresponding work in every other. The text-books are identical, so that a pupil moving from one part of France to another fits into the system as well in his new locality as in his old home. The French university professor presents his subject-matter by lecture as a rule rather than by text-book assignment and recitation, and there is little or no opportunity for questions from students or for student discussion of the topic presented. The science laboratory work is quite informal, as it is in our own schools. The instructor moves from table to table to give help, to supervise the students' work and answer queries. The laboratories are as a rule plainly at times meagerly furnished but equipped adequately for work.

The lecture method of presentation maintains also in the lycées and even in the primary school to a large degree. The text-book is of secondary importance. It was a matter of pride among administrative officers in the school system, often expressed to me, that "our teachers know their subjects so they can present them effectively, they do not have to send the pupils to text-books to learn." While in each subject in the lycée there is an authorized text the pupil uses it merely to clarify points he may not have thoroughly understood from the teacher's presentation. And he is free to use any other or many other texts if he so wishes, so long as he acquires a mastery of the matter given in the lectures.

There is no provision for laboratory work in science in the lycées, except in those with a distinct prevocational trend. The science department in the lycée is supplied with good demonstration apparatus in physics and chemistry as a rule, and during or after the lecture the experimental work is well given by a demonstrator, an understudy of the professor. I was informed that pupils were free to repeat the experiments for themselves, but such work would have to go on at the general demonstration desk of the professor which is too small to make such experimentation possible to more than a small fraction of the class. The lecture demonstration is evidently the chief reliance of the science instructor in the lycées.

And in the sciences other than physics and chemistry the demonstration is often farcically insufficient or entirely wanting. I recall one lecture on the internal structure of the coelenterates at which the instructor passed a small whole sea anemone, preserved in a test tube, and a specimen of coral as the sole exhibits; that is quite typical.

In very many cases, judging from my own observations I should say in the majority of cases, the building used for school purposes in France, from universities down, are buildings designed for other uses and they do not fill educational needs. So that the science departments as well as others are inadequately and inconveniently housed. There are some very beautiful university, normal school, lycée and elementary school buildings constructed for these specific ends, but such schools are all too frequently housed in old palaces, convents or monasteries. Crude board benches and desks that have descended from a time when monks crucified the flesh by their use are still in common use. France has not been lavish in building or equipping schools. Some of the recently constructed Paris lycées by their elegance indicate a more liberal policy. The Swiss schools seem more adequately and more elegantly housed as a rule, as do the English. Oxford is the achievement of ideal scholastic beauty both in the charm of location and environment and in the impressive multiplicity, mass and grace of her buildings. Some of the great public schools are marvelously impressive. The standards in secondary and primary school buildings in the smaller cities are excellent in both Switzerland and England.

When a boy in a science class of the lycée is called upon to make a topical recitation on some phase of the subject that has been previously presented in the professor's lecture he responds as a rule in a very creditable manner. He steps to the blackboard, clearly and logically states the matter and reproduces rapidly and effectively the diagrams with which the topic was illustrated by the instructor. He displays a well-trained memory and usually ability to think clearly. The pupils, as I heard them recite in France, Switzerland and England, make better topical recitations than in corresponding American schools. They know the subject-matter, are remarkably apt in stating this knowledge, and do not limit themselves to monosyllabic replies to the teacher's questions. It seemed to me that the French lads have a genius for mathematics and physics, and that these of all the sciences are particularly well done.

One is impressed with the atmosphere of seriousness in the lycées as compared with that of our high schools. There is apparently less frivolity, more concentrated effort looking toward a mastery of the

subjects presented, less attention to outside matters, in a word, more of the atmosphere of a professional school than of a secondary school. This difference in attitude of mind of the French and American school boy of similar age is easily accounted for.

The object of the French schools is to eliminate the unfit, to pass on the fit as speedily as possible to their appropriate trade or professional schools. The boy gets out of the elementary or primary school into the lycée or college and out of it into the university only on passing notoriously rigid examinations. Sixty per cent. of the boys who come up for the final examinations of the lycées each year fail to pass. Some of them, of course, persist, "read" for another year or even for several years until they finally pass. But many are deterred by their failure from entering a professional career and go into a trade or into business. On the other hand, it is the purpose of our American school to give to each prospective citizen the best education of which he is capable. We encourage him to stay in school and get all he can, even if his ability is distinctly limited. The French lad seriously faces examinations that bar his way to the achievement of his dear ambitions. The American lad perfunctorily takes his examinations, knowing that he will probably pass and that if he does not it is not a serious matter; he can try some easier subject. The American pupil's examinations come subject by subject, the French lad's on his entire course.

The French lad in the lycée sees his professional education beginning immediately on the completion of his course. He begins his study of medicine or law at seventeen or eighteen normally, and if he is precocious two or three years earlier. For he does not have to attend the lycée a given number of years or take a specified number of courses. He has simply to pass the final examination to obtain his bachelor's degree. By extra tutoring a lad of parts can and often does begin the course in medicine or law at fourteen or fifteen. In this country, in our best professional schools we postpone the entrance by requiring a college course in addition to the high school course, making sixteen years of schooling prerequisite to the professional school in place of the French lad's twelve or ten. We hope thereby that the entrant will have time to mature sufficiently to profit by his professional training. The French seem to force that maturity by facing the boy early with his professional responsibilities.

Then the French lycée instructor has no hesitation in using corporal punishment to enforce discipline. The schools have a military atmosphere of sternness and rigor. The lazy lad knows that lessons must be learned or he may suffer a flogging. Furthermore, the lycées and colleges are all boarding schools. Pupils from the

small country towns come to the city schools and live at the school. Some of these pensionnaires may go home for week ends, but the majority are in the school constantly. Even the day pupils from the city in which the school is located come to the lycée to study and play under supervision of the teacher at seven in the morning and leave at six in the afternoon. A few will come only for the recitations and study at home.

If our pupils were to remain all day under the supervision of the teachers, and if at the end of our high school course we were to give examinations covering the whole four years of work and fail 60 per cent. of the candidates, if we were to push the high school graduate at once into his professional school and if we were to introduce into our high schools a military discipline we might achieve the same seriousness of purpose, strenuousness of effort and facility of recitation that marks the science work of the French lycées. But we might lose that spontaneity, vigor, originality and self-confidence which the American high school pupil possesses in marked degree as compared with the lycée pupil. The latter gives an amazingly good reproduction of the professor's lecture and handles mathematical physics in the lycée in a way that would put to shame the American college student, but when he is switched off the beaten trail of memoriter reproduction onto a problem where initiative and mental alertness are needed or into chemical or biological subject-matter he is below par on the basis of American standards. That is merely a personal opinion, but it is based on "assisting" at many classes in a number of French lycées. The American university student in European schools is struck—and on this point many were questioned—with the accuracy and range of information possessed by the European university man. He has memorized the content of his lycée and university courses in a surprising way, probably because he must do so to pass the final stiff examinations. In how far he has sacrificed intellectual astuteness and independent resourcefulness in its accomplishment it is hard to judge. The American is quite sure the educated Frenchman lacks our own ebullitional buoyancy, alertness and ability to tackle forcefully and efficiently the changing problems. Face to face with a new situation we are as nimble on our intellectual feet as the proverbial cat and are at it at once with glowing optimism born of self-reliance. They seem bound by tradition, inert and pessimistic.

The preparation of the French teacher for his job is excellent as far as mastery of subject-matter is concerned. To teach in an elementary school he must have graduated from such a school or the corresponding primary school (equivalent to the completion of our fifth grade), he must have done two or three years' additional work

to prepare for the examination admitting to an elementary normal school from which he must graduate in a three-year course. The professor in a lycée is either a university graduate or else a graduate of one of the superior normal schools. In either case he will have done three years' work at least beyond his bachelor's degree, which it will be recalled he receives on graduation from the lycée. Entrance to the superior normal schools is by examination, which it is generally conceded is more difficult than the examination to the universities.

The work in the normal schools is largely subject-matter work given by men selected for their reputation as specialists and for their skill as teachers. There is in the elementary normal schools a brief course in general pedagogy and a year's required practice teaching, in which the candidate is under careful supervision and severe criticism. There is practice teaching also in the superior normal schools, except in the École Normale Superieure at Paris which, though aiming to be a teachers college, is rather, according to our standards, a university of high grade. Its faculty members are the most inspiring teachers in their several lines to be found, men who can stimulate research on the part of their students, who are in turn the most select group in France. The French normal school student is concerned first with the mastery of the subjects he is to teach, the art of teaching receives scant consideration except as he almost unconsciously copies the methods of his teachers, and the science of education is still quite below his horizon. The English normal schools (all private), devote much more time to pedagogy, and such courses are strong in the philosophy of education. The Modern Educators Library starts with a volume on "Education, its Data and First Principles" (Edward Arnold & Co., 1923) by T. P. Nunn, the brilliant director of the London Day Training College, which volume is saturated with it. The English are appreciative of our American attack on the problems of education by the experimental method, though they still stick largely to their philosophical and psychological approach. The French are largely unaware of American contributions along this line. The nearest approach to it encountered anywhere was in the Jean Jacques Rousseau Institute at Geneva, where Claparede is working along the lines of animal psychology that Thorndike traversed years ago, and Pierre Bovet, the director, is giving courses somewhat similar to Devine's at Columbia on sociological applications of education and studies of the delinquent boy. They are at least feeling their way into the scientific attack on educational problems and are conversant with the American results of such studies.

The French technical and trade schools are excellent and in

PLAN OF INSTRUCTION

INFANT SCHOOL—3 to 7 years of age

PRIMARY SCHOOL

5 years' course
7 to 12 years of age

GENEVA COLLEGE
Lower Division

3 years' course
12 to 15 years of age

GENEVA COLLEGE
Upper Division

4 years' course
15 to 19 years of age

Classes:

Classical, Technical,
Modern, Pedagogical

UNIVERSITY
5 Faculties

DENTAL SCHOOL

FEDERAL
POLYTECHNIC
SCHOOL

SCHOOL OF ARTS AND CRAFTS

5 Divisions

A. TRADES — *B.* APPLIED ARTS
6 to 10 terms. 14 years of age

D. MECHANICS
14 years. 6 terms

C. BUILDING AND CIVIL-ENGINEERING
E. APPLIED MECHANICS AND ELECTRO.

15 years. 6 terms

WATCH-MAKING SCHOOL
6 terms

HIGH COMMERCIAL SCHOOL
6 terms

SCHOOL OF FINE ARTS

CANTONAL HORTICULTURAL SCHOOL

AGRICULTURAL COURSES

PRIMARY SCHOOL

6th year's course
12 to 13 years of age
Compulsory

COMPLEMENTARY
SCHOOL
7th year's course
12 to 14 years of age

PROFESSIONAL, COMMERCIAL
AND INDUSTRIAL CLASSES

PROFESSIONAL ACADEMY
Classes for Apprentices
Classes for Women

HOUSE-KEEPING
SCHOOL

2 years' course
13 to 15 years of age
with COMMERCIAL AND
APPRENTICESHIP DIVISIONS
1 year

PROFESSIONAL SCHOOL

2 years' course
13 to 15 years of age
with POSTAL DIVISION
2 years and a half

EVENING CLASSES (Optional)

SECONDARY OR
YOUNG LADIES'
HIGH SCHOOL

Lower Division

3 years' course
12 to 15 years of age

Upper Division

4 years' course
15 to 19 years of age

Classes:

Literary
Pedagogical
Commercial

PREPARATORY CLASSES
for
UNIVERSITY

them the science is taught by the laboratory method, *i.e.*, when the acquisition of skill comes to be important individual laboratory work is made a feature of the education. Such schools seemed to me at their best in Switzerland. They are not only efficient individually, but they are admirably interrelated and adjusted to the rest of the school system. The Swiss seem very apt in vocational guidance and pupils are directed into that phase of educational endeavor that seems best fitted to their needs and capacities. The scheme of the schools in Geneva, reproduced from "Geneva, an Educational Center," is given to show the numerous schools maintained by the canton and their interrelations.

Summarizing, I should say that elementary science is quite as commonly studied in grades one to five in this country, and is better done than in the corresponding grades of France, Switzerland and England. Physics in French lycées and the corresponding schools of Switzerland is much more thoroughly mastered, particularly in its mathematical phases than in our high schools, but our pupils certainly do as well as theirs in chemistry and much better in the biological sciences. Enrollment in science in the English secondary schools is very light, the work is poorly done, the equipment very meager. In the technical schools, especially in Switzerland, the science work is admirably done with excellent laboratory and shop equipment for individual work, and such schools are so related to the academic schools as to facilitate the movement of pupils into them in accordance with the pupils' aptitudes. Teachers of science as of other subjects are well prepared, as far as mastery of subject-matter is concerned, in excellent normal schools or in the universities, but the courses in pedagogy are short and elementary, and there is almost no scientific study of the problems of teaching. The French and Swiss universities are on a par with our own average state universities as far as teaching staff and equipment is concerned, but the buildings are often poorly adapted to educational purposes. There are no universities in these countries that compare with our great universities in point of buildings and equipment. The science work in the universities is very like that in our own schools.

THE VACUUM—THERE'S SOMETHING IN IT[1]

By Dr. W. R. WHITNEY

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WE humans want better minds, broader horizons and greater understanding. These scientists assembled here are all at work in their respective fields searching for new truth, to improve the process by which our minds, our horizons, our powers and our outlooks grow.

When, in the middle ages, the great cathedrals of the world were being built, the mentality of men seems to have been directed to systematic subordination of creation rather than to active appreciation of it; to acquiring salvation, or "safety first," rather than knowledge or understanding. To-day you scientists, in seeking truth, think of "safety first" last.

We are told that if the total age of mankind be expressed as the life of a man of fifty years, and if he then looks back upon his progress, he will see that what marks his greatest advancement are events occurring in the most recent years. For example, such a 50 year man now sees that he had not learned to scratch the simplest records on stone until his forty-ninth year. All the immense advantages of printing have only existed three months for him. He has only just learned how to pass along what he has learned. The uses of steam, which now seem so necessary, were acquired only three or four years ago. The uses of electricity (street cars, lamps and telephones), which did not actually begin until about 1880, arrived the day before yesterday to this 50 year mankind. The automobile, wireless, X-rays, radium and most of the things which occupy our interests to-day, were actually discovered on this particular fiftieth birthday.

The power outside of his own muscles, which during the past two or three months he has learned to control, has grown to nearly twenty horsepower, or one hundred manpower, for every man in the country. Therefore, it makes only one per cent. difference whether all the men work like horses or not. But *guidance* of power is man work, because there are no machine-mentalities. Almost everything but thinking may be artificially done, but knowledge and understanding must be actively sought and used. Man is the only animal that can do this.

[1] Address expanded by Dr. Whitney at the suggestion of the Editor, after its delivery as a talk illustrated by experiments before the joint public meeting of the American Association for the Advancement of Science and Sigma Xi at Cincinnati, December 29, 1923.

Scientists know that research merely discloses new parts of the infinite unknown. Paradoxically, the enticing, helpful "unknown" increases as men continue to subtract *from* it. Progress in every line of experimental science follows the same law. The apparently narrow path gradually expands into unlimited, unexplored territory. With his new tools and his increased speed of communication, man finds that he can advance into the unknown faster than his ancestors could, and children seem to learn more rapidly than he did when he was young. The scientists of the twentieth century are legion. But scientists were anathema a short time ago. There is to-day more chemistry in the atom than there was in all "inorganic" chemistry a few years ago. There is more in the "sugars" now than there was in all "organic" when I studied it. There is more immunity in blood and more heredity in the microscopic chromosome than there was in all biology until recently. There is more crystal structure research by X-rays now than research in all mineralogy when Agassiz came to America.

There is special reason for my bringing before this group of scientists such a narrow field as the vacuum. It seems desirable that the applications of new knowledge be continually distributed throughout the separate sciences. In fact, that is probably the main advantage of an association of this kind and of such meetings as to-night's. I want to show that in a vacuum, of which one might say, "There is nothing in it" (and surely less than in anything else), there is, indeed, an endless amount of interest and utility. The American public now buys over a million dollars worth of glass vacua a week, but that is the least interesting part of the subject.

Everybody pretends to know that "nature abhors a vacuum." But he who started that tale merely meant that a good vacuum was hard to produce. As probably no one has ever made a vacuum with less gas-molecules in a cubic inch than there are people in the world, we can maintain that perfection in vacua is still precluded by nature.

My object is to review some studies in vacua so as to create not only the impression that any one may well do research work there, but also certainly anywhere else with pleasure and profit.

We all know that we see at night largely by the aid of vacuum lamps. Through other vacuum lamps, called X-ray tubes, we also see through opaque bodies. The light which illumines our microscope specimen has its analogue in the X-ray light which shows us the crystal structure of matter and the electrical formulae of chemical atoms. Our transcontinental wired telephony is possible through vacuum tubes which, in various forms, also permit our wireless broadcasting and wireless reception from the most remote

stations. The workman who keeps his drink hot or cold in a thermos bottle is clearly indebted to Sir James Dewar's application of the vacuum, but the scientist is still more indebted to it. All our steam power plants, including turbines, owe their success to vacua.

The latest arrival in the family of the chemical elements (hafnium) was discovered by trying it in vacua as an X-ray target. Our list of possible chemical elements was rounded off by Moseley's study of the X-ray spectra just in time to meet the wonderful discoveries of J. J. Thomson and Aston, all made in vacua. The latter showed that most of the elements, supposedly simple, are still mixtures of two or more similar elements (isotopes), while Professor Thomson's experiments disclosed by the positive ray method a whole series of new atomic compounds.

While the vacuum was not essential to the work of Millikan in isolation of the electron, yet the earlier work by Thomson and others, and much of the recent work on this ultimate constituent of matter, has been necessarily carried out in vacuum. To-day there seems to be no end to the studies which can be based on the fact that an atom or molecule of material may be separated electrically into a positively charged ion (carrying most of the mass) and a negatively charged electron (carrying most of the current).

Electricity

I may not be sacrificing historical truth too much if I claim that electricity at rest was the first kind known. This may be wrong from many points of view, but I wish to assume it. It then seems logical that electricity in simple direct motion should later appear and that still later we should find various directions and rates of its motion, if it moves at all. It will interrupt this line of argument if we doubt the existence of electricity as a thing, or question the existence of such different kinds of it as static and dynamic. The electricity of rubbed amber was the first and stationary kind (if you will admit that prior to Thales such things as lightning were something else). When the electricity first moved through metals the process was looked upon as a simple directed flow which proceeded until the charged body had delivered its charge.

Currents

This direct flow of electricity (a current) was strengthened in its hold on our conception by the great number of different chemical current-producers which followed the controversies between Galvani and Volta a century and a quarter ago. Primary and secondary or storage batteries without number were soon dis-

covered. The current from such batteries was exactly like that which the magneto electric machines produced, when these were developed, after Faraday had shown the effect of moving a wire through a magnetic field.

The direct current of such generating machines was much later followed by the alternated flow, and soon alternating current generators were made for different rates of reversal of direction. Sixty, forty and twenty-five cycle currents are now common and the user takes his choice. These frequencies were once accidents of convenience and economy. For some uses other widely different frequencies of alternation are very desirable, as in wireless, where 100,000 cycles are common.

Now the phenomena which have been found in vacuum tubes promise to give complete control over all these details of kind and frequency of current.

Electrical Control

As will be more fully shown later, when a unidirectional current meets vacuum tubes as though it would pass through them, it must find one particular kind of a tube, and the current's direction must be right, because some tubes will let it through only when it is both unidirectional and in the proper direction. These in themselves are rather remarkable things to expect of a vacuum, but as usual, the truth exceeds the expectation.

Catalysis

To give some idea of the extent to which vacuum studies may affect remote fields, let me mention chemical catalysis, the secret of most reactions of life. For example, it is known that mercury vapor in a vacuum, when illumined by light of a certain wave length, will absorb that light and turn the energy over to hydrogen, if hydrogen be present, so that this, in turn, will chemically reduce such substances as cold copper oxide. Here is a new kind of chemical process. It is the kind we have needed in order to begin to explain some of those life-reactions which vegetation discloses. That is, similar facts will probably be found to contain the explanation of the catalytic action of sunlight on growing plants.

And so the studies of phenomena in vacua may lead us into the most widely separated fields. The experiments which I have chosen for this evening are illustrations of this fact, and you must not, therefore, expect them to be very closely related.

Kinds of Vacua

I might say, as in our school-day essays, "there are different kinds of vacuum too numerous to mention" and then proceed to

mention them all, but I will merely illustrate several cases. A certain kind of vacuum is good enough for incandescent lamps because other factors besides the quality of its vacuum determine the death, or limit the performance of a lamp. But while formerly the incandescent lamp represented the very highest skill then reached in vacuum production, there are now other commercial vacua which are necessarily quite superior. This is true of good thermos bottles, X-ray tubes, radiotrons and other wireless tubes.

We should first, therefore, give brief consideration to the incandescent lamp, and note a few characteristics. Its low vacuum early disclosed electric cross-currents which would not have been found in much higher vacua. Study of these currents has led to the vacuum tubes used in wireless, and also to such remote disclosures as that distillation or evaporation of solids in vacuo proceeds in straight lines. The electrical currents in poor vacua are best known in luminous Geissler tubes, Moore tubes and Claude tubes, as seen on the streets of Paris, for example. They are themselves a large subject, but I will consider later on only one historically important experiment with them, the Hittorf experiment.

High Vacua

Electric currents through vacua where gas is so completely removed that it has no appreciable action are more strictly a part of my present paper. After the work by which the individual and indivisible negative electrical charge or electron was defined, it seemed quite fitting, though unexpected, to learn that these negative charges were exuded by hot bodies. The result of this disclosure formed the basis for most of the modern electrical phenomena in vacua. The activities of electrons are apparently the cause of most electrical and chemical processes. Their motions constitute electric currents and the currents are determined and controlled by voltage or potential difference.

Bees might illustrate electronics, though it's admittedly bad policy to push bees too hard. If bees represent electrons, then matter in general becomes the hives. When the hives are cold or in the dark the bees stay inside. Under the effect of heat or light the bees are induced to come out. Similarly, highly heated matter, such as tungsten, exudes electrons, and at ordinary temperatures light induces electrons out of metallic potassium, for example.

What are the bees or electrons going to do after they are out of the hive (or the metal)? That depends on impulse or pressure. They will fly in that special direction which tends to relieve that particular pressure. They proceed down the gradient. The electrons coming out of the metal (because of heat or light) will also

fly in that special direction which will tend to relieve the particular electrical pressure. They also proceed down the gradient. But if there is no particular impulse or gradient both bees and electrons hang around the source.

A lot of electrons, like bees, flying in a common direction, become a current or cathode ray. We might let them fly from the hot or lighted spot into a cold or dark one and until we heated or lit up the latter they would not come out. This unidirectional current corresponds to what takes place in rectifiers and kenotrons where we have impulses in the two opposite directions but one hot and one cold electrode in vacuo. If both hives (or both electrodes) are equal in temperature or illumination, no differential in current is possible, and with alternating impulses alternating instead of pulsating direct current passes. Thus bees illustrate two-electrode vacuum devices.

In the three-electrode vacuum tubes the third electrode is a sort of grid, or open fence, located between the hot and cold electrodes. This grid lets electrons pass freely except when it is negatively charged. Thus also the bees would pass through a wire fence when they might be stopped if their impulse to proceed could be suddenly removed there. The negative charge is used in the three-element tube to alter the intention of the migrating bees or electrons as often as desired, and this with the rapidity of light.

In the case of "wireless" it is the impulse from the antenna or loop, changing with every delicate change of voice-current or code-current, which, when led to the grid, charges it and thus controls the currents within the receiving tube. These controlled currents do the work in the telephone.

Everybody knows that wireless tubes are very sensitive. One cat-power of electricity used in New York actually puts the impulses into a wireless outfit in San Francisco, and at the same time it also puts the identical impulses into millions of other receivers. But some appreciable energy must be used by each receiver to direct the local battery which operates the head sets. This minute quantity of energy has been made significant as follows:

If a house-fly climbs up a window pane one inch he does a definite amount of work in lifting his body that much. If this work constituted the supply fed into the wireless tube from space it would suffice continually to actuate the outfit for a quarter of a century. This might interest a future student of telepathy, if the time comes to determine how far the energy of one thought may influence thought in a distant brain. It has not been possible thus far to determine the quantity of energy which is expanded in thought. Just keeping alive transfers so much energy into heat

that the additional energy transferred, when we think, has been too small to detect. But it need not be small compared to the power sensitivity of a wireless set.

Vacuum Tubes

Before showing the tubes I will briefly summarize them. The mere names of these modern applications of electrons in vacua are legion. The kenotron is a vacuum tube which changes high voltages alternating into direct current, and it has its counterpart for low voltages in the battery-charging tungar rectifier and the mercury rectifier. The various radiotrons, receivers and amplifiers of wireless are also the most direct applications of the action of negative electrons in good vacua. But X-ray tubes must also be considered in this connection, because X-rays are the result of the "bump," if you will, of rapidly moving electrons in vacua against the atoms of matter.

Electrons in motion are also directed and controlled by electromagnetic, as well as by electrostatic fields. Therefore, the magnetron and axiotron have to be shown or referred to. Because the mere illumination of such metals as potassium (like the high heating of other metals, such as platinum and tungsten) causes them to emit electrons, the photo-electric cell has to be included in our illustrations.

The electrons within the vacuum, as in a wireless detector tube, obey the inconceivably feeble electrical impulses received by the antenna. Conversely, the motion of electrons sets up impulses and waves in space. In other words, the vacuum detector may be made a wireless wave generator. They are used in most broadcasting stations.

Ether Waves

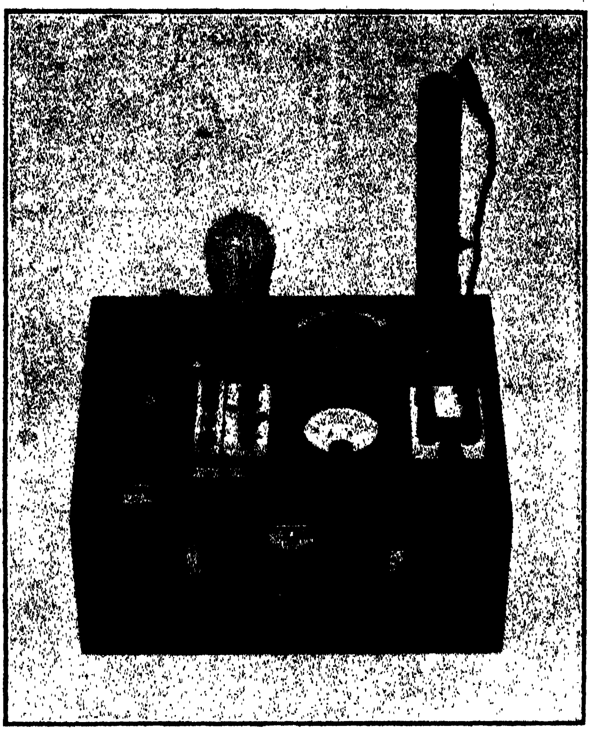
The wave lengths of the magnetic waves produced by the changes of motion of the electrons are very long in case of wireless (say 100–10,000 feet), millions of times shorter in ordinary light and millions of times shorter still in X-rays, but they are all in the same medium and all due to motions of electrons.

High Frequency

The induction effect of currents themselves is nothing new. Motors and generators depend on it, but the production of very high frequency currents is a recent result of vacuum tube development and so is part of our subject.

Special Emissions

Finally, to give an impression of the distance such work has gone, I have also added the case of a one-atom deep layer of thorium on tungsten in a vacuum and its effect on electron emission.



THORIUM EMISSION APPARATUS

In order to illustrate several of these vacuum phenomena simultaneously the Hewlett loud speaker is made part of the address. Microphonic currents are carried to one vacuum device or receiver and this acts in turn upon others as amplifiers. Telephone currents of large magnitude carrying the characteristics of the voice are thus produced and conducted through flat spiral coils close to and on both sides of a thin metal plate whose vibrating motion transfers to the air powerful sound waves corresponding to the original voice. This plate has to be subjected at the same time to induced currents from a direct current which is produced from the city alternating current by several vacuum kenotrons, as will be described.

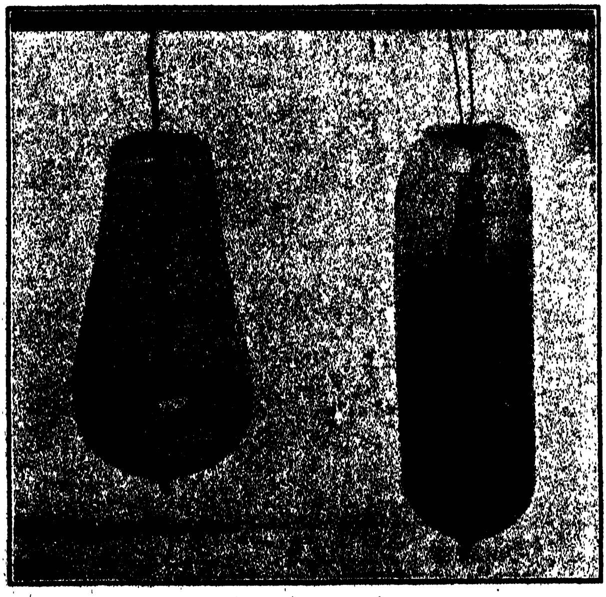
LAMPS

Now for some experiments. The first great use of vacuum was in incandescent lamps. I burn out an ordinary tungsten lamp by raising its voltage very much above normal. It lasts for a few minutes only, but it gives a light perhaps five times as efficient as we usually see. The lamp dies because the tungsten vaporizes or melts. The vacuum is not at fault. It is because of these limita-

tions that commercial lamps are so made that they burn at normal voltages on proper circuits an average of one thousand hours. If we were satisfied with a shorter life we could have a more efficient light, but experience has shown that we would be unwilling to submit to short life lamps in order to have the added efficiency. To lengthen the life of lamps much study has been made of distillation of metals in vacua, and of methods for returning the distilled metal to the filament. Much has also been done to make the deposit on the glass invisible or white, so as not to interfere with light transmission. Naturally, we are always on the lookout for metals, such as the newly discovered hafnium, which might possibly live longer as filament than tungsten now lives. Thirty or forty years of research work had been spent on high vacuum incandescent lamps before Dr. Langmuir showed us how to make still better lamps by putting back into the vacuum gases like argon and nitrogen.

Distillation

When the material of a filament distills in vacua it does not meet interference to the motion of its molecules, and the distilling substance proceeds in straight lines from the heated source. This is often observed when an incandescent vacuum lamp arcs or burns out. Metal shadows of interior parts of the lamp are then often cast onto the walls. This is shown more clearly when a metal like gold is evaporated from the surface of a tungsten filament in



Vacuum Distillation

vacuum. By interposing a design (in this case a star) the shadow in gold was cast on the glass. This simple phenomenon is mentioned because it fits in with the kinetic theory of gases and explains many things observed in vacua. The "mean free path" of molecules or atoms is very long in good vacua, and so straight line distillation occurs.

Hittorf

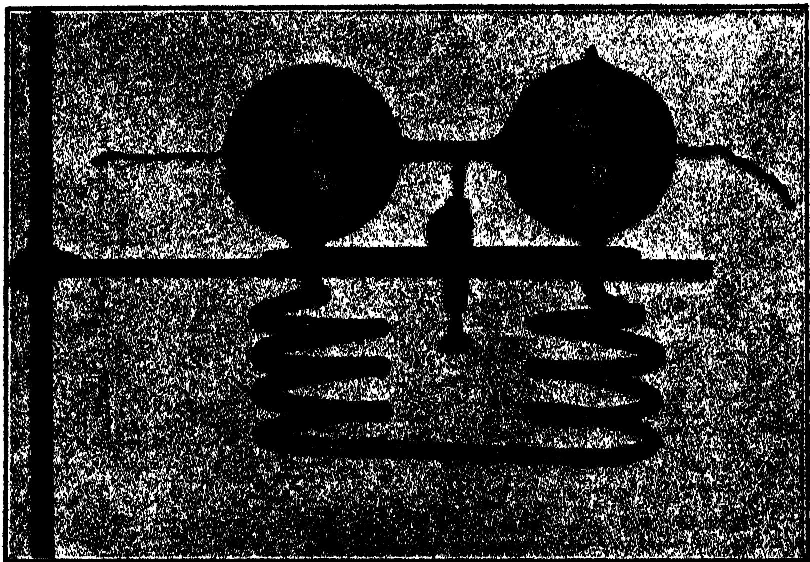
In the historic Hittorf experiment two vacuum bulbs, each carrying an electrode, were joined together by two glass tubes, one very short and one exceedingly long. When electric current was passed from one bulb to the other, it evidently chose the longer instead of the shorter path, because the longer tube became highly luminous, while the shorter one did not. This is a quality of electrical conduction in vacua where small quantities of gases still remain, but it can not be gone into here.

Edison Effect

The historic Edison effect was discussed and its relationship to pure thermionic currents shown. Where it was once thought that nearly visible particles of the filament were shot across the space between filament legs in vacua, now we recognize in very high vacua only the unidirectional motion of negative electrons.

Rectifiers

In vacuum tubes like the kenotron these electrons pass from the

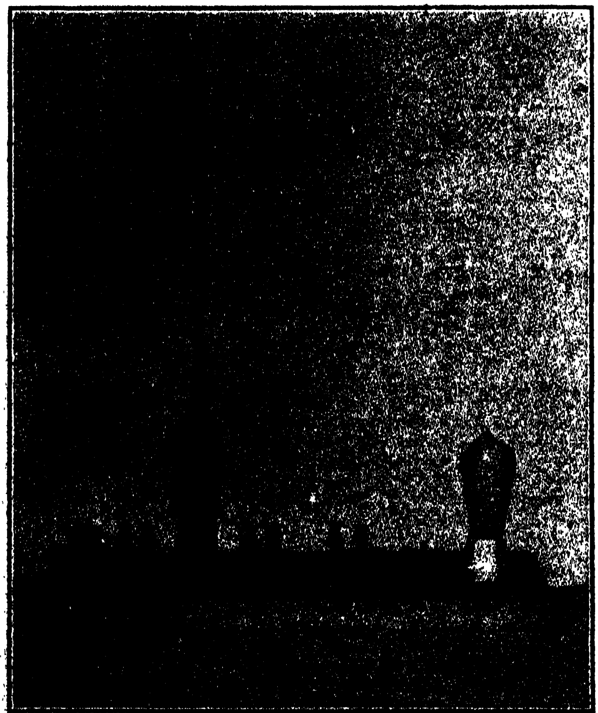


Hittorf Tube

hot filament to an electrode commonly called the "plate." This pure emission current is the basis for the so-called rectifiers because only when the filament is negative does any current flow across the space. When gases are present greater currents may be carried, because by the ionization of the gases the moving electrons produce new conductors from the gas molecules. Thus the tungar rectifiers, containing a little argon and the older mercury vapor rectifiers, involve the same principle. Without some gas present the negative electrons, by their very concentration, constitute a space charge which limits the current. This space charge is removed by the ions produced within the gas when present.

Radiotrons

When we interpose a grid or wire screen between the hot filament and the plate of the two-electrode tube or rectifier, we have what we now so commonly use in wireless for receiving, for amplifying and for production of high frequency currents. The discovery of the controlling or triggering action of the third or intermediate electrode was made by De Forest. A negative charge applied to this electrode or grid interrupts or modifies the electron stream, the current, from the hot filament to the plate. As it takes

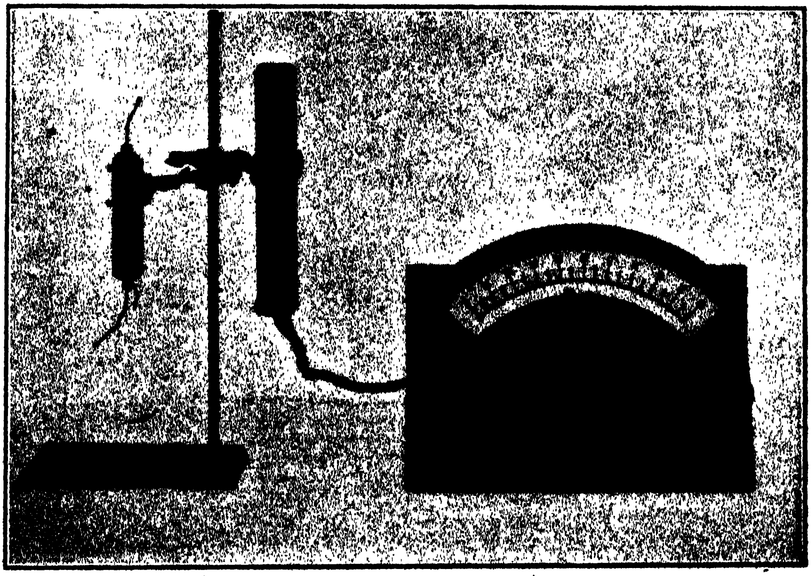


Radiotron Principle

almost no energy to charge this grid (little more than a "token" of energy, voltage), the slight power from a wireless antenna in its fluctuation may be used to control or to trigger, or to let through corresponding jolts of greater energy, which are in turn supplied by some local battery. In the experiment shown, an ordinary incandescent lamp was lighted by current which was passing through a three-electrode tube from hot filament to plate. Its light indicated this current. The grid, or antenna-wire, was sticking up from the tube so that it could "pick up" electric charges from space. A small negative charge was produced on a rod of insulating material by merely rubbing it with a piece of paper. The charge so produced caused the lamp to go out, or light up, as the charged rod was brought near to or removed from the exposed end of the grid wire.

Magnetron

As the negatively charged grid cuts off the current of the three-element tube, so an external magnetic field will also do it in the two-element tube, by so influencing or directing the moving electrons that they can not reach the plate. Such a device, called a magnetron, was shown. This particular magnetron, consisting of a cylindrical plate in a vacuum and a central filament within it, had a coil of wire wound on the outside of the glass. A feeble current was sent through the coil from a battery. A magnetic field produced within the coil by this current was intentionally made about equal to that



Magnetron

of the earth's magnetic field, so that by moving the whole apparatus about in space (thereby at one time adding to the earth's field, at others opposing it), the magnitude and direction of the earth's magnetic field could be disclosed by a meter which indicated the resultant current. When the magnetron pointed towards the north pole, the meter showed no current, while in other positions currents were measured.

Axiotron

Another useful vacuum tube of this type is one in which the magnetic field of the filament current itself becomes great enough during each current cycle to deflect the electrons so that they will not reach the plate. By this tube, "the axiotron," the frequency of an alternating current may be doubled or direct current be changed into alternating.

Photo-Electric Cell

Another vacuum tube is the photo-electric cell. One of these was shown connected with a relay to a lamp so that when light shone upon the cell, the burning electric lamp was extinguished, and was relighted on cutting off light from the photo-electric cell. In other words, it turns on the lights when it is dark, and turns them off when it is light. This depends on the fact that some metals like potassium emit electrons when light falls upon them. These electrons in vacua constitute a current when they are made to move by the electrical impulse. To repeat, applying potential

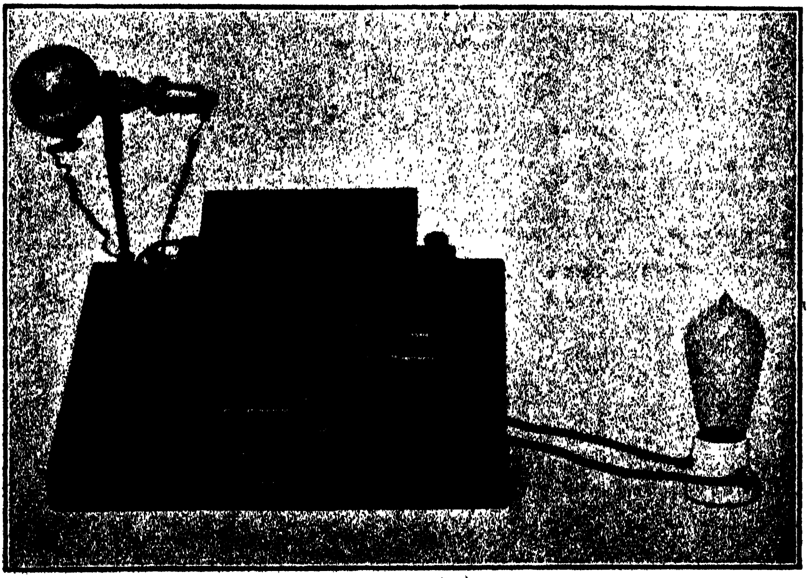
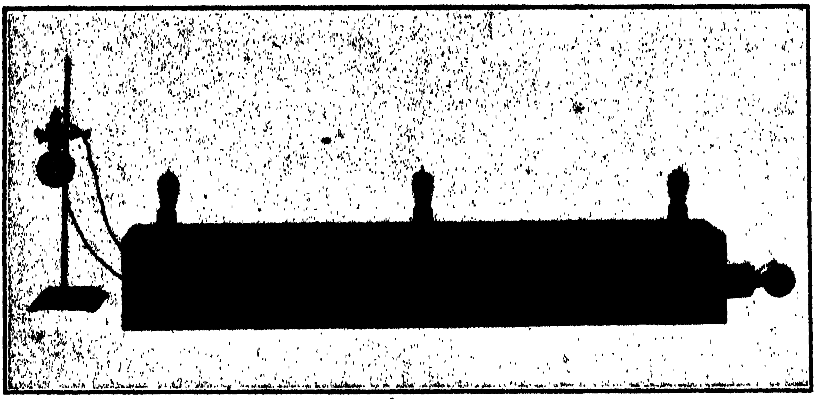


Photo-Electric Cell



THE NERVE

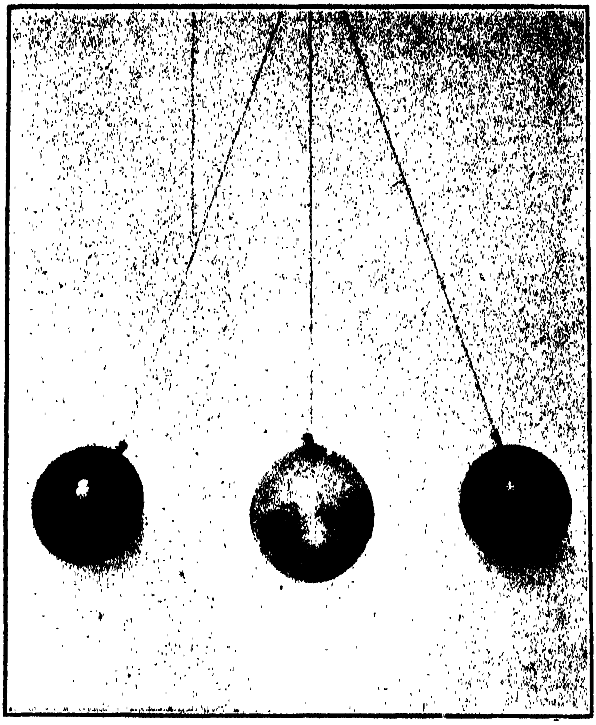
to a vacuum tube having a potassium electrode and another electrode for leading off the current causes current to flow as negative electrons from the illumined metal, and this current actuates the electrical switch which turns off the lighting current of the burning lamp.

THE NERVE

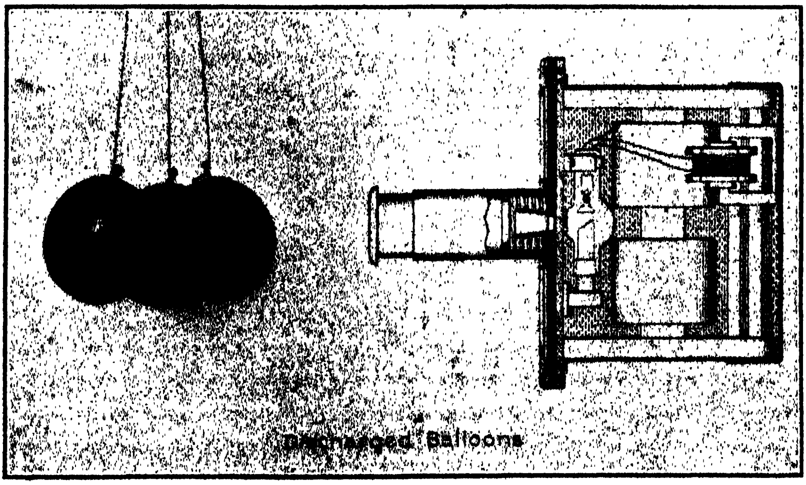
This led to the next, an ambitious physiological experiment. A photo-electric cell was made to represent a crude "eye" which was connected to a so-called "nerve" leading to a "brain." The nerve was merely a long box having electrical capacities and suitable amplifiers or three-electrode tubes within. The capacities served to slow down the apparent rate of flow of the feeble current from the artificial eye so that indicating lamps along the top of the box or "nerve" would light up, one after another, as the impulse from the "eye" passed along that path, or the nerve. After the last lamp was thus lighted by these amplified currents an electric bell rang to indicate reception at the "brain"-end of the circuit. This was not shown as a reliable replica of the real nervous system, but as an application of the vacuum tube which amplified the slight energy available and necessary for the experiment. With such slight energy it became practicable to show the delayed transmission and reception which is necessary for an illustration of nerve action. Nerve impulses travel much slower than electricity usually does, and this slow speed was one objection to visualizing nerves as electrical conductors until Crehore and Williams showed that nerves might be naturally so constructed as to transmit slowly.

X-RAYS

In order to show another vacuum product (the X-ray tube) an effect of X-rays was demonstrated which is not usually thought of



Charged Balloons



Discharged Balloons

in connection with X-rays. Three rubber balloons, suspended close together by long cords, were first charged electrically by being rubbed on the head of the speaker. They then repelled each other

and stood stationary in space as at the corners of a large triangle. As soon, however, as a feeble beam of X-rays was projected towards them they quickly discharged and fell to their original position in contact with one another. X-rays ionize air or make it conducting so that the balloons could not retain their mutually repelling charges. This is the basis of a method for measuring the intensity of beams of X-rays.

Spectra

References were made to the various applications of X-rays, as in the study of internal structure of crystalline chemical compounds and elements. Cathode rays, currents of negative ions in vacuo when speeded up by high voltage, produce by their impact X-rays which are characteristic of the material on which they impinge; one may say characteristic of the mass of the atom of the substance of the target. It is through this fact that the X-ray spectra of the elements considered as to wave lengths are arranged in the same order as the atomic masses in the periodic table of Mendelejeff, and by this very method the newest known element, hafnium, has been recently added to the known metals. Referring again to our bee analogy, let a fast-flying swarm strike bells so hard that they make them ring. From the sound of muscial notes we guess roughly the sizes of the bells. We could thus place them in their musical series. The sound corresponds to the X-rays produced when the bees are electrons of cathode rays and sound waves are ether waves. The mass of the bell is disclosed by the tone or frequency; the mass of the atom, by the same sign, is disclosed by the ether wave-frequency. When a certain mineral was used as a surface for the electrons to hit, a new musical note in the ether was found. It was recorded photographically. Its place in the scale of elements had been predicted as accurately as middle C on the piâno might have been predicted if it had never been heard.

With higher voltages the velocity of the cathode rays (or electrons) always increases. In the X-rays thus far produced, however, the penetration or transparency is practically limited to about a quarter of an inch of lead. It is interesting to note that the similar rays from radium, the so-called gamma rays, can penetrate nearly a foot of lead. This corresponds to an exceedingly high electromotive force. Thus radium rays (gamma rays) might be made in vacuum X-ray tubes if millions of volts were applied.

Atom Layers

An apparatus was shown, devised by Dr. Hull, which is essentially a two-electrode vacuum tube, the tungsten filament having

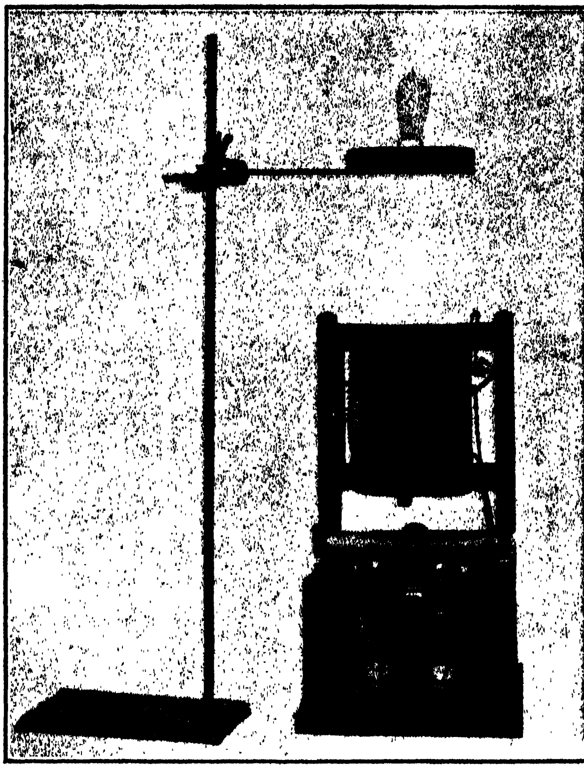
a little thorium in it. At a certain very high temperature this thorium rapidly diffuses to the filament surface. This thorium surface then has the peculiar power of emitting electrons a hundred thousand times as rapidly as pure tungsten at the same temperature. An ordinary lamp was lighted in this experiment by letting this thorium electron-emission current flow throughout the lamp filament. The vacuum tube containing the thorium-coated tungsten also contained a little gas. When the lighted lamp was short-circuited for an instant by a switch, the potential on the vacuum tube was thereby greatly increased, and this caused positive ion bombardment of the filament and thus tore the thorium all off the tungsten surface so that very few electrons were being emitted, *i.e.*, those characteristics of pure tungsten at that temperature. Then the load (the lamp) could no longer be "carried" by the electron current. To repeat, the heavy positively charged gas ions under the impulse of the raised electrical potential act like a powerful sand blast and effectively clean the thorium from the tungsten, thus greatly reducing the emission current. By highly reheating the filament for a few seconds only, a fresh layer of thorium diffused anew to the surface of the filament from within the tungsten, so that, then, at the previous lower temperature the load or lighting current for the lamp was carried as before by electrons emitted from the thorium surface. This was mentioned as a proof of the production of a layer of thorium on the tungsten only one atom deep. The electron current from thorium on tungsten is greater than from pure tungsten and also than pure or massive thorium and is maximum when the single atom layer is present. This is confirmed by experiments on partial recovery of the surface and supported by thousands of successive repetitions of this experiment on one filament.

High Frequency

The production of high frequency current by means of pliotrons was shown and an ordinary incandescent lamp was lighted by being brought within a foot of a coil which was carrying the current of several million cycles. This was said to be about as near to wireless transmission of power as we now have. This high frequency principle is also being used by Professor Northrup of Princeton for special electric furnaces. In these, the induced currents in the material of the crucibles or the material to be heated generate high temperature through local resistance.

Loud Speaker

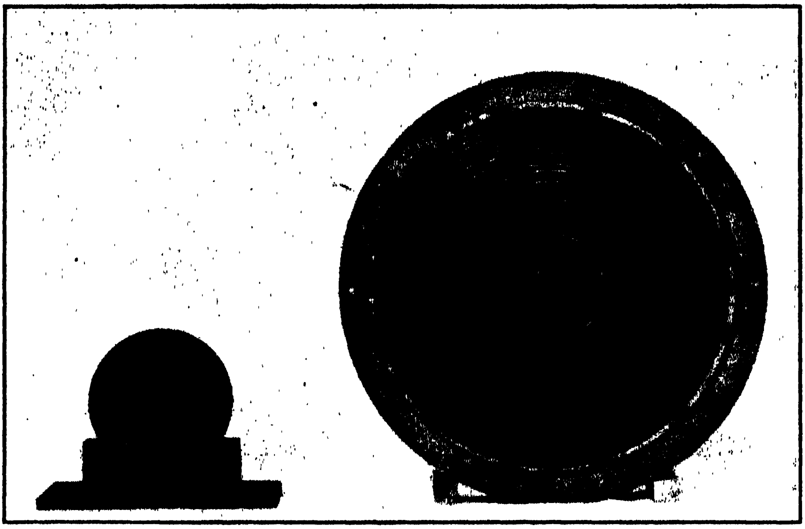
During part of the address a loud speaker devised by Dr. Hewlett was in use. This consisted of a 26-inch flat conducting disc in



HIGH FREQUENCY OUTFIT

a magnetic field. The vibrations of the disc corresponding to the voice currents produced the sound waves without the intervention of a horn. The use of vacuum tubes in this device consisted in the following:

A microphone was placed near the speaker and the sound waves of his voice caused to be generated in this microphone feeble electromotive forces which were applied to the grid of a pliotron. These feeble electromotive forces caused relatively large variations in the electric current flowing between filament and plate, which in turn were used to secure larger electromotive forces to be applied to the grid of another pliotron. By the use of several amplifying pliotrons the original feeble electrical currents were multiplied several thousand times and supplied to the loud speaker which reproduced the original sounds with many times the original volume and great faithfulness of quality. To operate this amplifier of pliotrons required a direct current of several hundred volts. This was obtained by first transforming the power from the ordinary alter-



HEWLETT LOUD SPEAKER

nating current lighting circuit to a relatively high voltage, next rectifying this high voltage alternating current by means of kenotrons, and finally smoothing out this pulsating current by means of appropriate electric circuits.

The high degree of faithfulness of reproduction realized in this loud speaker is due partly to the absence of a horn, eliminating horn resonance (one of the usual sources of distortion in a speech reproducer), and partly to the method of vibrating the diaphragm by forces which are distributed fairly uniformly over its surface, instead of being acted upon in a very limited region, as is the case in most other loud speakers. This feature eliminates rattling and ringing of the diaphragm or the production of high overtones by the diaphragm vibrating in its partial modes.

ERNEST FOX NICHOLS

The distinguished physicist, director of research in the Nela Laboratory, Cleveland, who died on April 29, while reading a paper before the National Academy of Sciences

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

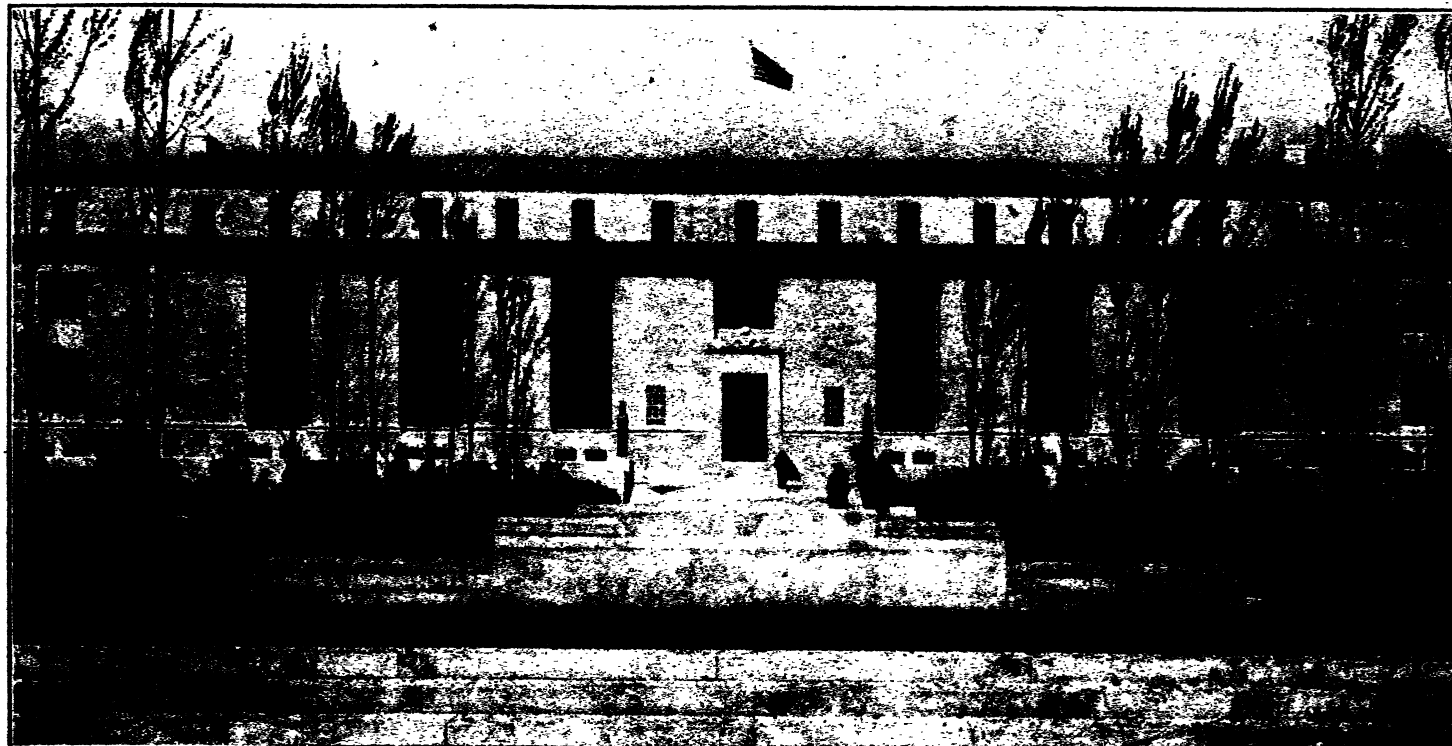
ERNEST FOX NICHOLS

At the moment when he was completing his demonstration of new radio waves on April 29, Ernest Fox Nichols fell back upon the exedra in the rotunda of the new building of the National Academy of Sciences. His wife rushed to his side with restoratives, but in vain, for a few minutes later, President Michelson announced his death, and the adjournment of the session of the academy. Shortly after, the academicians were walking in procession down the marble steps through the newly planted garden following the body of their distinguished colleague.

Professor Nichols had died as he had lived, in the active promotion of science. Research was his life work, and although he had twice been tempted into administrative office, by serving as president of Dartmouth College from 1909 to 1916, and by accepting an appointment to the presidency of the Massachusetts Institute of Technology in 1921, he gladly returned again to his investigation of the laws of light.

Visible evidence of his ability as an experimenter was close at hand, for while he was yet speaking visitors in a room next to the rotunda were examining the apparatus with which he proved the pressure of light. By touching a button of this ingenious mechanism, one can turn on an electric lamp and actually see for himself that the beam of light exerts a definite pressure upon whatever object it strikes. This pressure is so minute that it had never been observed until Professor Nichols demonstrated it twenty-four years ago. Yet as we now know the sunlight falling daily upon the earth amounts to a weight of more than 100,000 tons. It is this light pressure that makes the tail of a comet by driving the infinitesimal dust particles away from the sun. It is also light pressure that keeps the gaseous stars like Betelgeuse swelled out to their gigantic size in opposition to the attraction of gravitation tending to draw them together into a solid mass. The actual demonstration of the fact that light produced a pressure effect was of especial importance, since it is involved both in Maxwell's theory of the similarity of electrical and light waves and also in Einstein's more recent theory of relativity.

The life of Ernest Fox Nichols was cut short at fifty-five, yet few of his elder colleagues in American science have accomplished more. He was born in Leavenworth, Kansas, and being early left an orphan, was brought up by his uncle, General Fox. He went first to the Agricultural College at Manhattan, Kansas, and afterwards studied at Cornell, Cambridge and Berlin. At Berlin University, under Professor Rubens, he began his work on the long wave lengths about which he was talking when he died. While professor of physics at Dartmouth, he developed a radiometer of such delicacy that he was able to measure the heat that comes to us from the stars. In his last paper he was engaged in closing the "missing link" between the longest of the heat waves and the shortest of the radio waves, thus completing the series of the spectrum which runs from the "gamma



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FAÇADE OF THE NEW BUILDING OF THE NATIONAL ACADEMY OF SCIENCES AND OF THE NATIONAL RESEARCH COUNCIL, DEDICATED AT WASHINGTON ON APRIL 28

rays" of radium, which are a hundred thousand times shorter than light waves, to the "wireless waves" which are miles in length.

It would seem almost that he had a premonition that he would not complete his paper, for he began by saying that he would reverse the usual order of procedure and present his conclusions at the beginning. So he showed his last slide first. His auditors assumed that he did this in order to avoid being interrupted by the president before he had completed his demonstration, as speakers often are. His paper was, indeed, left unfinished as he feared, but it was a higher power than the president of the academy who notified him of the expiration of his allotted time.

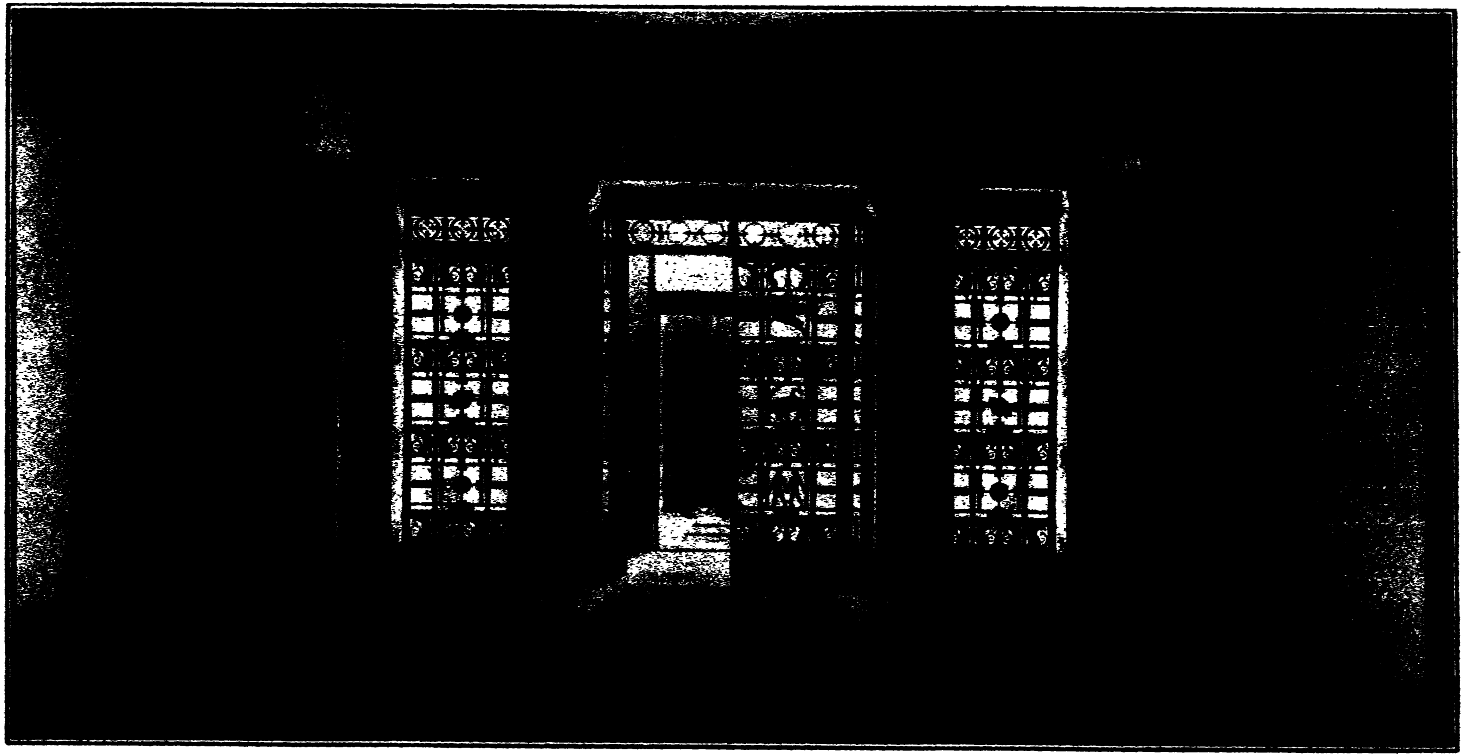
A LACTIC ACID THEORY OF THE UNIVERSE

We know that chemistry plays an important part in modern industry. We know that certain chemical substances in minute amount, such as the hormones that naturally exist in our bodies and the drugs that we unnaturally put into our bodies, have an effect upon our health and temperament. I wonder if we can not go farther and inquire if our metaphysical notions may not also be traced back to chemical causes. How, for instance, do we get our abstract ideas of space and time which form the framework of the external world?

Our concept of space seems to be founded primarily upon the movement of our muscles. It requires more of an effort to reach a yard than to reach a foot. We get more tired in walking two miles than in walking one. Of course it does not always require the same effort to cover a given distance with the arm or by the legs, but the relation is much more constant than the data given by the sense of sight, where objects change their shape and size quickly, as we or they move about, in a way that must be most perplexing to a baby. Even yet we may be deceived by our eyes and mistake a bush on the next hill for a tree on the horizon. Our sense for sound is still more unreliable. So we fall back for substantiation and verification of extent and distance on some sort of muscular exertion. We measure space by our feeling of fatigue. It is much the same with our sense of the lapse of time. Two hours' work seems longer than one. Though time seems to go faster or slower, depending on whether our employment is enjoyable or distasteful, yet we average it up in the long run as we do our spatial estimates, and consider space and time objectively as constant.

Now what is the cause of the feeling of fatigue on which we base our ideas of extension and duration? It is evidently dependent in some way upon the accumulation of the waste products of muscular exertion, such as lactic acid. "The fatigue maximum is associated with the lactic acid content in the muscle."[1] "The rate at which lactic acid is produced almost certainly varies directly with the activity of the muscles."[2] A minute and a half of violent exercise has been found to increase the percentage of lactic acid in a sample of the blood, taken twelve minutes afterwards nearly five times, not counting the much larger quantity that had been oxidized.[3] A man weighing 150 pounds may by exercise produce 3.5 ounces of lactic acid. "The exhaustion following long-continued moderate exercise is due to the diffusion of lactic acid out of the muscles where it is slowly oxidized and removed."[4] Whenever we exercise a muscle lactic acid is pro-

[1] *Chemical Abstracts* 16, 2545 (1922); 17, 816 (1923).
[2] Bainbridge, "Physiology of Muscular Exercise.".
[3] *Chemical Abstracts* 17, 3532 (1923).
[4] *Ibid.*, 15, 2311 (1921).



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ENTRANCE HALL TO THE BUILDING OF THE NATIONAL ACADEMY OF SCIENCES

duced in proportion to the exertion and when the lactic acid is made more rapidly than it can be carried off by the blood and consumed we get the sensation of fatigue. So our measure of space is somewhat dependent upon the amount of lactic acid in the body.

If this argument does not convince the reader, I may approach it in another way. Our only knowledge of space comes from our exploration of it by movements of limbs or body. A spherical and stationary amoeba, a mere drop of jelly, can not be considered as having any conception of spatial extent. When a little lactic acid accumulates on the surface of the amoeba the protoplasmic granules at that point absorb water from other parts of the organism by imbibition. This produces a pseudopodium, or extempore limb, with which the amoeba may reach out or propel itself along. When the lactic acid vanishes surface tension overcomes the imbibition and the organism resumes its resting spherical form. According to this theory the origin of limbs and of movements comes from an accumulation of lactic acid.

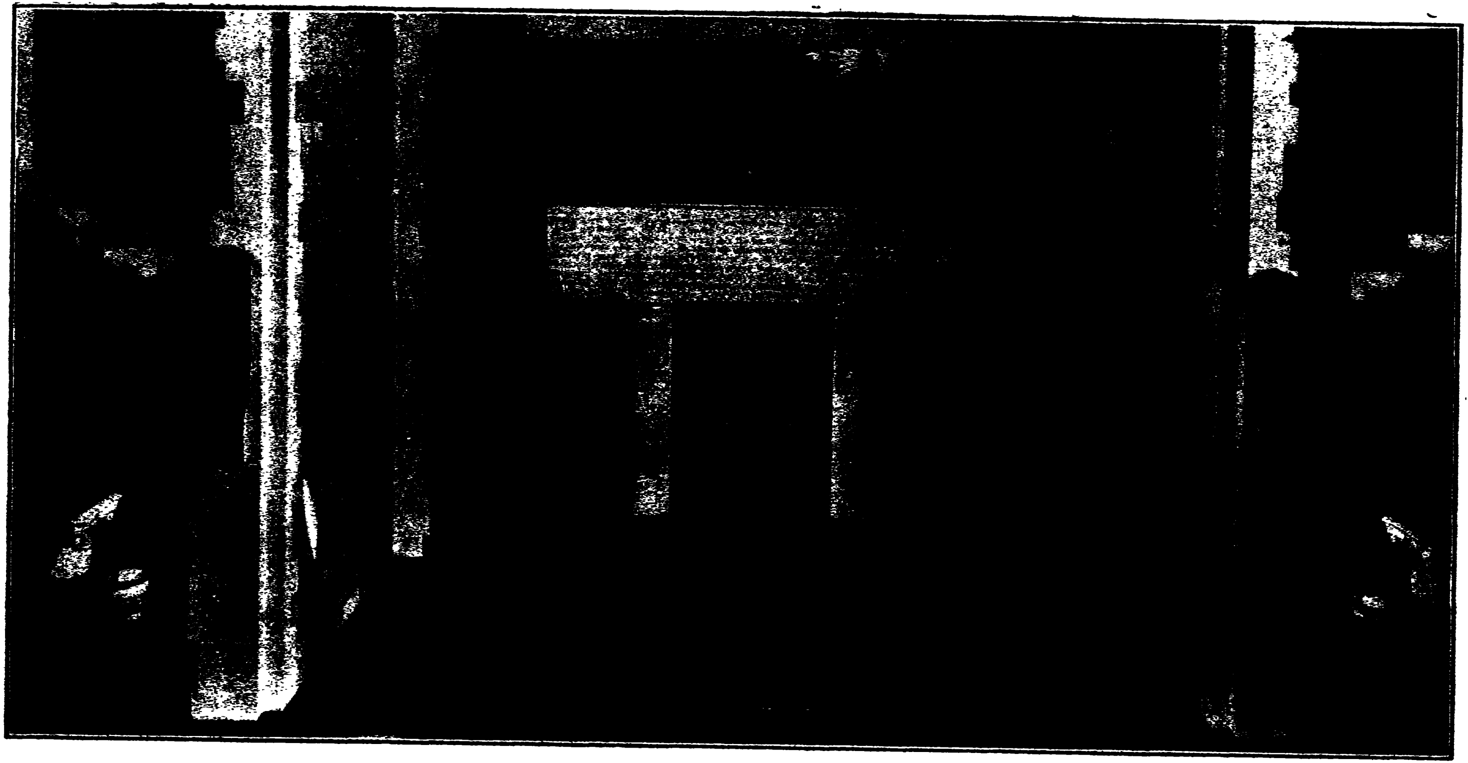
It seems to me then that there is a chain of casual connection between lactic acid formation and our conceptions of space and time. If so, it means that our metaphysics has a chemical foundation; that geometry is essentially a branch of chemistry; that astronomy likewise depends on chemistry; that Einstein's theory of a four-dimensional time-space continuum has its origin in deficient oxygen to keep down the lactic acid. In short, we have a lactic acid theory of he universe. Q. E. D.

PREDICTING THE MOVEMENTS OF ELECTRONS

THE essence of science is prophecy. Until a student of nature can tell what is going to happen beforehand his knowledge is of uncertain validity and little value.

The science of astronomy had its birth twenty-five hundred years ago when the Greek philosopher, Thales, predicted the coming of an eclipse of the sun.

To-day a new science is being born, quite as marvellous as astronomy and much more important to the world. It may indeed be called "the astronomy of the atom," since it deals with the orbits of the electrons in their revolution about the central nucleus. This reminds us of the arrangement of the solar system with the positively charged nucleus standing for the sun in the center and the corpuscles of negative electricity revolving around it. But there is this important difference. The solar system is stable and the planets pursue almost exactly the same course, century after century, fortunately for us who are living on one of them. It would be decidedly disconcerting to us, if, for instance, Mars should be carried off by a comet making the grand tour of the universe, and Saturn should suddenly drop into its place. Or if our earth should be detached from the sun and swept off through space and be drawn into the sphere of influence of some other star like Sirius, which we might not like so well as our own sun. Yet that sort of thing happens frequently with the electronic planets inside the atoms. And it has now been found possible to predict what particular orbit a loosed electron will fall into. This is possible because when an electron shifts from an outer orbit to one nearer the nucleus it sends out a flash of light of a definite color, that is to say the waves of the emitted light are of a certain length and a corresponding frequency. The "frequency" means the number of waves passing a given point in a second. The longer the waves, of course, the less the frequency.



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Rostrum in the Rotunda of the Building of the National Academy

The frequency and wave length of the light radiated by any star or incandescent gas can be determined by the location of the bright lines in its spectrum.

Professor R. A. Millikan, of the California Institute of Technology, has recently discovered a way of stripping off one by one the outer electrons from an atom, and he can tell in advance with amazing accuracy just what sort of light will be emitted by such a stripped atom. Last year Dr. Millikan was awarded the Nobel Prize in physics for the ingenious piece of apparatus that enabled him to catch and count the loose electrons and calculate their electric charge. He has this year penetrated still further into the mystery of atomic structure. His new discovery was to have been explained to the National Academy of Sciences on the afternoon of April 29, but on account of the tragic death of Dr. E. F. Nichols while addressing the Academy that morning no further papers were read during the day. But Professor Millikan has kindly consented to give a plain account of what he has done and what it means.

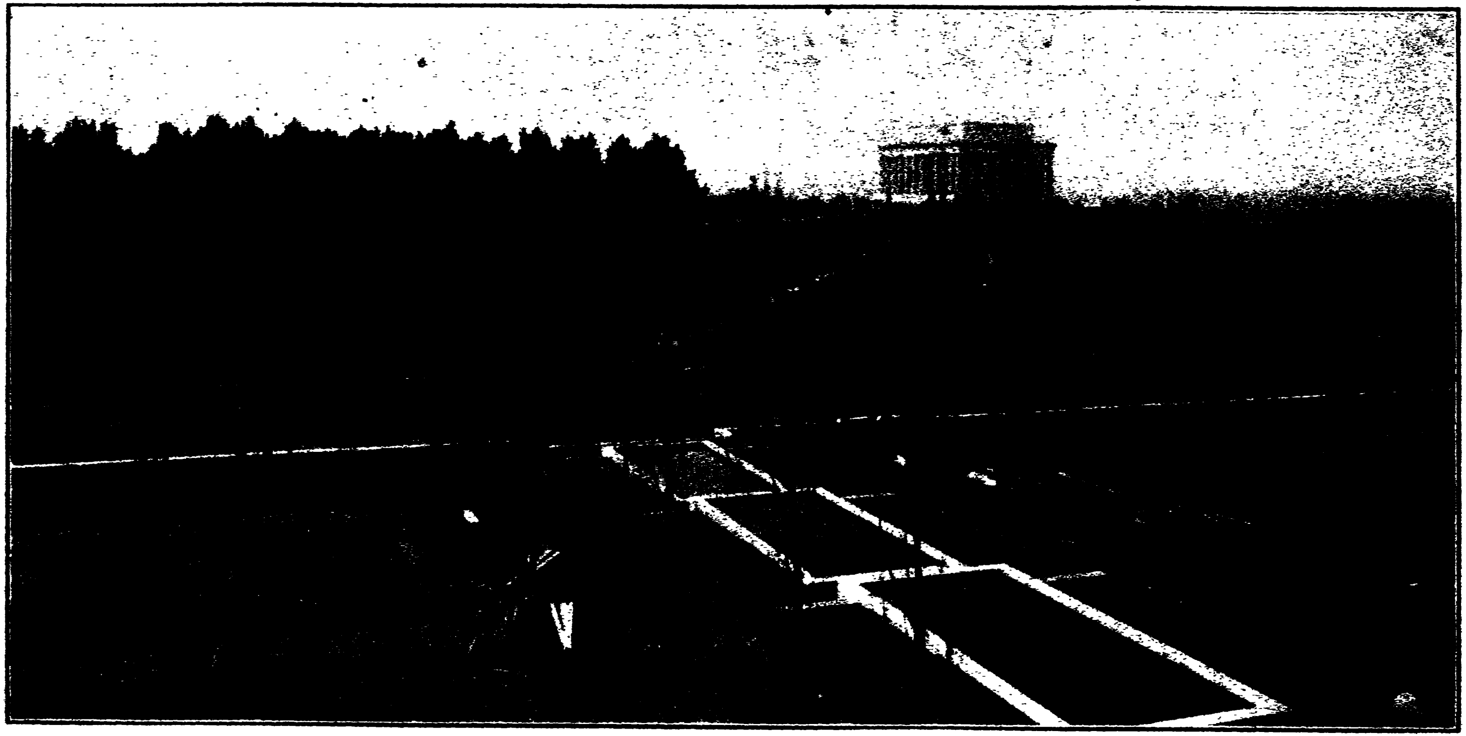
THE ASTRONOMY OF THE ATOM

By Dr. Robert A. Millikan
California Institute of Technology

The world is just entering upon a period of development of atomic mechanics, or of the astronomy of the atom, which has many points in common with the period of development of celestial mechanics which occupied the two or two and a half centuries following Galileo. Celestial mechanics was made possible through the invention of the telescope. The spectroscope bears precisely an analogous position with respect to atomic mechanics. The telescope made it possible to determine the exact orbits of heavenly bodies and to check by precise observation of such phenomena as the time of eclipses the theoretical results which are consequences of the Newtonian laws. Similarly, to-day the spectroscope has furnished the physicists with means for the quantitative testing of the recently developed laws of atomic mechanics, and it is to-day furnishing as exacting proof of the orbital theory of electronic motions as the telescope furnished a century earlier for the orbital theory of the motions of heavenly bodies.

The present paper shows not merely what kind of phenomena can be predicted with the aid of the orbital theory of electrons and atoms, but with what amazing precision these predictions are verified by the test of experiment. These results have been made possible because of the development of high vacuum "hot spark" spectrometry with the aid of which we were able first in 1920 to push three or four octaves farther into the ultra-violet than preceding investigators had gone. For the sake of simplicity, I shall at first confine attention to the radiations emitted by one particular atom, namely, the atom of boron, familiar to every household because of the abundant use of boracic acid for disinfecting purposes.

The atom of boron is the fifth in the order of increasing atomic weights, hydrogen being the lightest, helium the next, lithium the next, beryllium the next and boron the next. This means that the nucleus of the boron atom contains five free positive electrons and that five negative electrons are held outside the nucleus, or just enough to make the normal boron atom electrically neutral. Of these five electrons two have been proved heretofore, and are again proved in this paper, to be close to the nucleus. The re-



View of the Lincoln Memorial from the Terrace of the National Academy

maining three are four or five times more remote from the nucleus and are called its valence electrons. For the sake of later comparison it is useful to recall that lithium possesses one of these valence electrons, beryllium two, boron three, carbon four, nitrogen five, oxygen six and fluorin seven, which is the highest number possessed by any known atom having the possibility of combining with other atoms at all.

Now the interesting property of our hot sparks, which are very high potential discharges in the highest vacua between electrodes from a fraction of a millimeter up to one or two millimeters apart, is that such hot sparks possess an extraordinary ionizing power. Mr. I. S. Bowen and myself at the California Institute of Technology have recently definitely proved that these hot sparks have the power of stripping a great many atoms completely of all their valence or outer electrons. These stripped atoms of lithium, beryllium, boron, carbon and nitrogen, for example, are then completely similar atomic structures, save for the fact that the central charge increases in the ratios one, two, three, four, five, in going from lithium to nitrogen. This is the first time that it has become possible to compare the radiating properties of such a long series of similar atomic structures and the discovery of a means of obtaining such a series has furnished the opportunity of getting some very interesting checks upon the theory of electronic orbits.

Now the theory of electronic orbits in atoms is similar to the theory of planetary orbits in astronomy save that the atoms have one restriction unknown to the former. While celestial mechanics permits of the existence of as many orbits as you please around a given central sun, atomic mechanics permits of a very limited number of orbits whose radii progress (in the simple Bohr theory) in the ratio of the squares of the numbers one, two, three, four, five, etc. Atomic mechanics also differs from celestial mechanics in the mechanism by which the existence of a particular orbit can be experimentally tested. Thus, the most exact test which astronomy offers for the correctness of hypothetical planetary orbits is the prediction of the instant of passage of two such orbits through a given line so as to produce an eclipse. If the eclipse occurs at the predicted instant, it is considered that the theory which made the predictions possible has received extraordinary quantitative support. In the astronomy of the atom, on the other hand, we can not observe an eclipse, but what we do observe is the frequency (the reciprocal of the wave-length) of the radiation emitted when an electron jumps from one of its possible orbits to another. These jumps always occur from the orbits more remote from the nucleus to those which are closer to it and the difference in the energies of the electrons in the two orbits (which I shall call the energy of the orbit itself) is found to be in every case exactly proportional to the frequency emitted. It is this frequency which the spectroscope immediately brings to light as a spectral line whose wave length, and therefore whose frequency, it enables us very accurately to measure.

The whole number of different orbits which are possible in such a simple nucleus-electron-system as is furnished by the hydrogen atom has long been accurately known experimentally, and these known orbits have been fitted beautifully and accurately into what is known as the simple Bohr theory.

This theory requires that if the charge on the nucleus should be successively given the values one, two, three, four, five, the frequencies of all the orbits would be increased in the ratios one, four, nine, sixteen,

twenty-five. Now the discovery of the possibility of stripping all the valence electrons off the atoms of lithium, beryllium, boron, carbon and nitrogen has given us the means of comparing the radiations from what are in effect simple nucleus-electron-systems in which the charge on the nucleus increases in the ratios one, two, three, four, five, provided always that we are comparing orbits in different atoms which are so remote from the nucleus that the pair of electrons which, as indicated above, is near the nucleus in all the atoms may be considered as exerting their forces as though they were in the nucleus itself.

To return now to the consideration of the stripped boron atom. When Mr. Bowen and I began to get evidence that our hot sparks were stripping the boron atoms of all their valence electrons, we set to work to predict exactly what sort of frequencies (or of wave lengths) we might expect to be emitted by the stripped boron atoms as a single electron, in being drawn into this stripped atom, began to jump between the possible orbits which ought to exist about it. Thus, on the basis of our knowledge of the spectral lines emitted by hydrogen, we predicted at once that an electron in jumping from the fifth to the fourth of these possible orbits would produce a line of just nine times the frequency of the radiation produced when the hydrogen atom electron jumped from the fifth to the fourth orbit. We computed in this way that this stripped boron atom ought to have a line whose wave length was 4,500 Angström units, that is, a line in the blue region of the ordinary visible spectrum. No such line had ever been observed with boron thus far, but no one had before worked with light like that given off by our hot sparks which one could expect would produce stripped boron atoms. So we made our exposure, developed our plate, and found our predicted line which no one had ever seen before at exactly the wave length 4,499.0, or within one part in 5,000 of the predicted spot. In other words, our predicted "eclipse" in the field of astronomical orbits had occurred at exactly the right time.

We also computed the radiation that would be produced when the electron circling around the stripped boron atom fell from the third orbit to the second and got 678 Angströms. We looked up our table of boron lines in the extreme ultra-violet which we had published last January and found that we had recorded a strong line at wave length 677 Angströms, but if this were indeed due to the stripped boron atom it ought to be, like the so-called D line of sodium, a doublet, that is, a pair of lines very close together. It had not appeared so on our old plate, but the spectrograph had not been one which could have separated this pair, even if it existed, so we built a new spectrograph of higher resolving power and took another photograph of this line and found that it was indeed a doublet, just as our orbit theory demanded, the two components of which had wave lengths of 677.01 and 677.16.

We have now brought to light all the lines which were to be expected from the stripped boron atom and by checking all of these predictions by experiment we had proved with absolute certainty that in our hot sparks we were producing stripped boron atoms.

But some one says: Are these results dependent upon your orbit theory of the motion of electrons? Thus far, not completely, but in the next stage they are completely so dependent. I have spoken of the doublets which we found produced by the stripped boron atom. Now the principal lines in the spectrum of hydrogen are also doublets, and a beautiful theory was developed by Professor Sommerfeld for explaining these doublets.

He showed that there ought to be two orbits, one circular and one elliptical, which would have exactly the same energy if it were not for the fact that the mass of the electrons in the elliptical orbit should grow greater as its speed increased in going through perihelion and smaller as it went through aphelion, and that because of the dependence of mass upon speed which is required by the Einstein theory of relativity. He further computed exactly with the aid of that theory the differences in the energies of two orbits, the one circular and the other elliptical, and found that this theory, which yielded a formula in which there were no undetermined constants at all, predicted completely and exactly the observed frequency separation of the hydrogen doublet. We now tried this relativity doublet theory upon the doublets which we had found in lithium, beryllium, boron and carbon and found that this purely theoretical formula predicted exactly the observed separations in all cases. We then predicted from this formula the separation of the doublet which ought to be produced by the stripped nitrogen atom and looking in the nitrogen spectrum found a nitrogen doublet with precisely the correct separation and at a wave length which we could also predict by our theory. We had thus brought to light a most powerful instrument with which we can now analyze the light that comes from any kind of a source, for example, a very hot star, and know at once by comparison with the theory of observed lines whether stripped atoms of a whole series of substances exist or do not exist in the sources. In this way, we have definitely proved the existence in our hot sparks of stripped atoms of lithium, beryllium, boron, carbon, nitrogen, sodium, magnesium, aluminum, silicon, phosphorus and sulphur, this last atom having been stripped of six valence electrons, phosphorus of five, silicon of four, aluminum of three, magnesium of two and sodium of one.

These methods bring to light new ways of going on eclipse expeditions in the study of the astronomy of the sub-atomic world, and they reveal new possibilities for the reading of the conditions existing in the stars. Truly, we are just now entering upon a period of the fascinating study of the astronomy of the atom, a period in which the spectroscope is the instrument with which we must bring to light wonders no less fascinating than those which the telescope has revealed in the study of the stars.

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